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Feasibility trial of a selection of perennials and grasses in stormwater planters using heavy clay soil in Pyhra, Lower Austria.

Master Thesis
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in Landscape Planning and Landscape Architecture

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Vienna, March 2021

Affidavit

I hereby swear that I have compiled this Master Thesis without external help and without using sources and aides other than those permitted and that the sources have been cited verbatim or quoted textually in the places indicated.

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Abstract

Raingardens or Bioretention facilities are being increasingly used as rainwater management systems in many cities around the world. By reducing runoff into conventional (pipe based) drainage systems they can significantly reduce risks from flash flooding, whilst also increasing biodiversity as well as improving the environmental and aesthetic quality of urban areas. Stormwater planters are an important element which can be used in raingarden systems particularly in locations with limited space. In areas which are deemed to have unsuitable natural ground conditions for raingardens - such as heavy clay soil - soil replacement is usually advocated, which is both expensive and a further burden on the environment.

This trial investigated whether a selected group of nine perennials and grasses can survive and give an attractive display in a clay based substrate in a stormwater planter, thus avoiding soil replacement. The intended use is aimed predominantly at domestic garden settings, but could be used in public spaces as well. In both situations it is important that the display is low maintenance – needing little weeding and no additional watering.

Two stormwater planters were used, one filled with heavy clay soil which was improved with sand and compost, and as a control the same species were also grown in a second planter containing the substrate used by St. Pölten council. The species were chosen based on their suitability for use in rain gardens, and the local climate, as well as to create an attractive display comprising of grasses for structure, perennials for seasonal colour and ground covering plants to reduce weeding.

Of the species trialled: *Alchemilla sericata* 'Gold Strike', *Gypsophila repens, Hemerocallis x cultorum* ‘Stella d’Oro’ and *Pennisetum alopecuroides* ‘Hameln’ all performed very well and can be strongly recommended for use in this way.

The trial took place close to St. Pölten over the growing season in 2019.

Abstract - Deutsch

„Rain gardens“, begrünte Versickerungsflächen, werden in vielen Städten der Welt zunehmend als Regenwassermanagementsysteme eingesetzt. Durch die Reduzierung des Abflusses in das Kanalsystem können sie das Risiko von Überflutungen erheblich reduzieren, die biologische Vielfalt erhöhen sowie die Umwelt- und Ästhetikqualität städtischer Gebiete verbessern. „Stormwater planters“, bepflanzte Regenwasserrückhaltesysteme, sind eine wichtige technische Ausführungsart der *rain gardens*. In Gebieten, in denen ungeeignete natürliche Bodenbedingungen wie beispielsweise schwere Lehmböden als Ausgangsmaterial für *rain gardens* vorliegen, wird in der Regel ein Bodenaustausch empfohlen.

In dieser Arbeit wurde untersucht, ob neun ausgewählte Stauden und Gräser in einem *stormwater planter* mit einem Substrat auf Lehmbasis überleben und eine attraktive Gestaltung bieten und so auf einen Bodenaustausch im Retentionsbereich verzichtet werden kann. Ein solches System mit vorhandenem Substrat richtet sich an private Gartenanlagen, kann aber auch im öffentlichen Raum eingesetzt werden. In beiden Situationen ist es wichtig, dass die Pflanzgestaltung pflegeleicht ist.

Für den Versuch kamen zwei *stormwater planters* zum Einsatz, von denen einer mit schwerem Lehmboden, versetzt mit Sand und Kompost, gefüllt wurde. Zur Kontrolle diente ein zweiter gleich bepflanzter *planter*, der mit dem für öffentliches Grün ortsübliche Substrat der Stadt St. Pölten gefüllt wurde. Die Pflanzenauswahl erfolgte für wechselfeuchte Standortbedingungen und eine ganzjährig attraktive Gestaltung.

Von den getesteten Arten zeigten *Alchemilla sericata* 'Gold Strike', *Gypsophila repens, Hemerocallis x cultorum* ‘Stella d’Oro’ und *Pennisetum alopecuroides* ‘Hameln’ eine sehr gute Leistung und können daher besonders empfohlen werden.

Der Versuch fand in der Vegetationsperiode 2019 in der Nähe von St. Pölten statt.

Table of Contents

1. Introduction

In the last years there has been an increase in interest in rain gardens, with many cities particularly in the USA, UK, Europe and Australia installing them. Rain gardens collect rain water from roofs and sealed surfaces and prevent much of it (or all of it) from entering the conventional drainage system. They also help to make urban areas more attractive, increase biodiversity and can help reduce urban temperatures due to the cooling effect of evaporating water. They are also frequently used to reduce flash flooding which can occur when conventional drainage systems are overwhelmed by sudden large rain events.

One element used in some rain gardens is the stormwater planter. Here rainwater (usually from a roof) is directed into a specially adapted planting bed. This slows down the flow of water, irrigates the plants in the bed and dramatically reduces the amount of water that would otherwise flow directly into the conventional drainage system.

Parts of the city of St. Pölten in Lower Austria as well as the surrounding area have a heavy clay soil. This soil is generally unsuited to rain gardens as water penetrates it so slowly and it can become waterlogged. Despite this in the last years an increasing number of water retention measures have been incorporated in and around the city. This usually involves soil replacement which is both expensive and a further burden on the environment.

The aim of this Master’s thesis is to trial a selection of perennials and grasses planted together in this heavy clay soil in a stormwater planter. The object is to see if these plants can be recommended for use in rain gardens in the St. Pölten area, whilst avoiding the need for soil replacement. As such the plants would need to not only survive but also provide an attractive display over the growing season. Although predominantly aimed at use in domestic gardens, if successful the plants could be trialled in the future in public areas in the St. Pölten area where the heavy clay soil could be improved rather than a full soil replacement being carried out. The trial was conducted in Pyhra, close to St. Pölten over the growing season in 2019.

1.1 Research Questions

- **Which of the plants trialled can be recommend for use in stormwater planters on the heavy clay soil in and around St. Pölten?**
- **Which of the plants trialled are unsuitable for use on heavy clay soil in a stormwater planter?**
- **Does the planting combination used provide an attractive display over the growing season?**
- **Does the stormwater planter require additional irrigation during long dry periods?**
- **How much maintenance is required to keep the display looking good?**

2. Literature Overview

2.1 Terms and Definitions

Various different terms and definitions are used throughout relevant literature regarding rain gardens.

Stormwater is defined in the Chesapeake Bay Glossary from the United States Environmental Protection Agency as: “Any precipitation in an urban or suburban area that does not evaporate or soak into the ground, but instead collects and flows into storm drains, rivers and streams.” (EPA, 2021a)

Green Infrastructure (GI) and the term rain garden itself can be used to describe a host of different elements or a single garden system. “More complex rain gardens with drainage systems and amended soils are often referred to as bioretention.” (EPA, 2021b). The City of Portland (2020) in the USA defines Bioretention as, “Bioretention facilities are vegetated systems that capture, store, and filter stormwater through a layer of soil. They can be designed to infiltrate or discharge the filtered runoff.” (p. 3-45). Hunt et al. (2015), mentions more terms stating: “Bioretention systems, also known as biofiltration systems, biofilter or rain gardens, is a common stormwater mitigation measure.” (p. 1). Whereas Morash et al. (2019), states that, “The terms rain garden and bioretention, are now often used interchangeably to denote a landscape area that treats stormwater runoff.” (p. 1). Furthermore, geographical location can affect the terms used, for example: “The approach is called Sustainable Urban Drainage System (SUDS) in Europe and Water Sensitive Urban Design (WSUD) in Australia.” (DHAKAL & CHEVALIER, 2016, p. 1113)

For the purposes of this paper the term rain garden will be used to mean an entire rainwater management system with stormwater planters seen as a single element within this system.

2.2 What a rain garden does

Different elements used within rain gardens - also referred to as Low Impact Development (LID) measures - can have different intentions, some are used to slow the flow of water, some filter the water to remove pollutants, while others are used to capture or store it. Some allow ground infiltration with the aim of reducing or preventing altogether the rainwater from reaching the sewer system. “Rain gardens are an effective, attractive, and sustainable stormwater management solution for residential areas and urban green spaces. They can restore the hydrologic function of urban landscapes and capture stormwater runoff pollutants, such as phosphorus (P), a main pollutant in urban cities and residential neighbourhoods.” (MORASH, et al., 2019, p. 1).

Rain gardens have multiple functions; one of the most important of these is to change the traditionally held view of rain being a nuisance that should be transported away in pipes as quickly as possible. “Rain gardens optimize the value of any rain that does fall […] it is sound environmental practice to reduce or eliminate dependence on irrigation water in areas with regular water shortages, while at the same time introducing landscape design elements that will deal with periods of heavy rainfall that might normally give rise to flash flooding.” (DUNNETT & CLAYDEN, 2007, p. 14). This is becoming increasingly important due to the effects of climate change. The last summers in Austria have tended to have long dry periods, when many people then irrigate their gardens, followed by intense rain showers that can cause flash flooding.
Another function of rain gardens which is particularly beneficial in cities is that they can dramatically improve the aesthetics of the urban environment and increase biodiversity. “Rain gardens are largely composed of flowering perennials and grasses, together with scattered shrubs-an ideal mix for encouraging a great diversity of wildlife.” (DUNNETT & CLAYDEN, 2007, p. 16). It is this use of flowering perennials and grasses which also makes them suitable for domestic residential gardens and hence the basis for this paper.

2.3 Rain garden elements

Some of the more commonly used rain garden elements are: green roofs, swales, ponds, water tanks and butts, and stormwater planters.

A short explanation of each element follows:

2.3.1 Green roofs

Green roofs or living roofs can be built on flat or sloping roofs where retainers are used to stop the substrate sliding down. They can be built on a large scale such as on industrial, commercial or public buildings or on smaller scales such as house roofs, or even on the roof of garages, car ports and sheds. (DUNNETT & CLAYDEN, 2007, pp. 53-55). Two main types are low maintenance extensive roofs (figure 1) which have a shallow layer of substrate and are often used to grow sedums; and intensive roofs (figure 2) - ranging right up to roof gardens - which have a thicker layer (or layers) of substrate and can be used to grow grasses, perennials, shrubs and even small trees. These require more maintenance and stronger structural capabilities of the building to take the weight. (DUNNETT & CLAYDEN, 2007, pp. 67-68). They directly intercept rainfall which irrigates the plants. The amount of rainfall leaving the roof area will be dramatically reduced as will the speed of the water flow. Green roofs also increase biodiversity, improve the aesthetics of roof spaces and can help with the insulation properties of the building keeping it warmer in winter and cooler in summer.

Figure 1. Extensive (green) roof planted with grasses in Vienna (Edward Gunn).

Figure 2. Intensive (green) roof with a 25 cm substrate layer on top of a 5 cm drainage layer, the planting includes perennials, grasses and small shrubs; Horticultural School (HBLFA Gartenbau Schönbrunn) Vienna (Edward Gunn).

2.3.2 Swales

Swales are long shallow channels in the ground (figure 3) that are used to transport and infiltrate rainwater into the surrounding area. “Where the natural soil type is relatively impervious, such as a heavy clay soil, gravel, grit or sharp sand can be incorporated into the top layer.” (DUNNETT & CLAYDEN, 2007, p. 108). The swale itself is often grassed, with perennials, shrubs or trees planted along its edges. As well as slowing the flow of water and irrigating the landscape they prevent rainfall from entering the sewer system and can be used to filter pollutants out of the water. “The aim is for them not to be permanently full of water, but to encourage accumulation of rainfall during storms and to hold it for a few hours or days while it infiltrates down into the soil, and/or is transported further to a detention pond or basin.” (DUNNETT & CLAYDEN, 2007, p. 106). A variation is the car park swale (figure 4) in these “Vegetation is essential to filter contaminants that may be in the run-off from the paved areas. Trenches lined with limestone chippings can also be used to trap any oil and petrol before the water enters the swale.” (DUNNETT & CLAYDEN, 2007, p. 117).

Figure 3. Vegetated swale at the University of Innsbruck (Edward Gunn).

Figure 4. Car park swale collecting surface runoff from a car park at the University of Innsbruck (Edward Gunn).

2.3.3 Ponds

Ponds can be used to collect rain water preventing it from reaching the conventional drainage system. “Ponds are one of the final elements in the stormwater chain, providing a final resting place for run-off water. An important function is pollutant removal.” (DUNNETT & CLAYDEN, 2007, p. 121). Unlike traditional ponds, the water level of a pond in a rain garden will fluctuate depending on rainfall. “Ponds will have a permanent pool of water within them, which rises following heavy rainfall and is then released over a period of time.” (DUNNETT & CLAYDEN, 2007, p. 121). “If the pond is already at full capacity, then any inflow will push water out of the pond and a regular overflow option is then necessary.” (DUNNETT & CLAYDEN, 2007, p. 121). They can dramatically increase the biodiversity in an area as well as being used to filter pollutants from the water.

In domestic gardens where the water is pollutant free they can also be used for swimming (figure 5). “The first swimming ponds were built in Austria in the mid-1980s as an ecological alternative to chemically treated and cleansed swimming pools. […] They are a chemical-free combination of a swimming pool and a rain garden.” (DUNNETT & CLAYDEN, 2007, p. 155).

Figure 5. A swimming pond in a private residential garden in Lower Austria (Edward Gunn).

2.3.4 Rainwater tanks, water butts and barrels

An alternative way of managing rain water is to collect and store it for later use. The simplest types are water butts and barrels (figure 6) which can be used to collect and store rainwater usually taking it directly from the downpipe of a building. The water can be used to fill watering cans to manually irrigate gardens. Larger scale water collection is known as water harvesting. “Water harvesting involves capturing rainwater from a house, barn or shed roof, filtering it and cleaning it, storing it for use in non-drinkable applications such as garden watering, toilet flushing, washing machine use and car washing.” (DUNNETT & CLAYDEN, 2007, pp. 99-100). This usually involves large tanks which can be situated underground and often have a pump to bring the water back out.

All of these reduce the amount of rain that would otherwise go directly into the conventional drainage system as well as reducing the amount of tap water that would otherwise be used for garden irrigation or other purposes.

Figure 6. Water barrel collecting rain water from a house downpipe (Edward Gunn).

2.3.5 Stormwater planters

Stormwater planters are essentially a large container of substrate and plants that rainwater is channelled into. “In addition to reducing pollution, flow rates and volumes can be managed with these planters to moderate flows from buildings.” (DUNNETT & CLAYDEN, 2007, p. 94). If filled with attractive planting schemes they also have great potential for improving the aesthetics of urban areas. They are smaller than other rain gardens elements and so are suitable for many locations. As they are self-contained systems that use uncontaminated rain water (when taken directly from a roof) they are an ideal option for this trial. The study of the plants can be carried out without other factors such as water pollutants affecting the results. By using two of them it also enables an easy comparison between the improved heavy clay soil and the St. Pölten council’s substrate which is being used as a control. It is for these reasons that they have been selected for use in this trial, and they are, therefore, looked at in much greater detail in chapter 3.

2.4 Stormwater chains

Stormwater chains are when a combination of elements are used together. (DUNNETT & CLAYDEN, 2007, p. 45). By having one element flowing into another a far greater affect is achieved; more rainwater can be captured, stored, or allowed to infiltrate into the ground. For the purposes of this trial stormwater planters were used in isolation, however, when installed in a residential or public setting it would be highly recommended to use them as part of a stormwater chain where practical to do so. As an example, the overflow from a stormwater planter could be connected to a swale or gully to transport water further through the area and allow further infiltration into the surrounding ground (an example of this is demonstrated in figures 7 & 8). Where space allows they could then flow into a pond. Alternatively a green roof could be installed on a building before the stormwater planter in the chain. (DUNNETT & CLAYDEN, 2007, p. 45).

Figure 7. Stage 1 of a stormwater chain: overflow from a stormwater planter flows into a gully, at the University of Innsbruck (Edward Gunn).

Figure 8. Stage 2 of a stormwater chain: gully then flows into a swale, at the University of Innsbruck (Edward Gunn).

3. Theory of Stormwater Planters

3.1 Definition

The City of Portland (2020), in Oregon, USA gives the following definition for a stormwater planter:

> "Planters are walled landscape areas that capture, store, and treat stormwater runoff. They can be designed for total or partial infiltration depending on soil infiltration rates. They can be lined if conditions don't allow for infiltration."
> (CITY OF PORTLAND, 2020, pp. 3-55)

As their design can be modified they can fit into any physical location including residential, commercial and industrial settings. They are also ideally suited to small schemes where space does not allow for other larger rain garden elements.

Stormwater planters are essentially large containers which are partially filled with soil and plants. They are often made of concrete or brick for longevity but for the purposes of this trial they will be constructed from wood as they are not intended to remain beyond the one season of the trial. It is important to consider waterproofing of the planters especially when they are situated adjacent to a building, which is where they are most commonly found. In the case of new builds, they can be planned along with the architectural design of the building. It is also possible to site them away from a building – particularly if retro-fitting to an existing building. They work by collecting the rainwater which falls onto a building's roof; this is channelled into them using the downpipe on the building. The water can then soak through the soil and be absorbed by the plants. Under the soil is a gravel layer to aid drainage, which helps to stop the soil becoming waterlogged. Space is left between the top of the soil level and the top of the planter so that during heavy rainfall the water can fill up this space and then soak in over the coming hours. "The design aim is that water does not remain in the planters for more than 12 hours-preferably the water drains in 2-6 hours. This is essential to prevent long-term waterlogging and anaerobic conditions, which are detrimental to plant growth." (DUNNETT & CLAYDEN, 2007, pp. 95-96). In order that water infiltrates through the planter at a suitable speed the top 45 cm should be filled with amended soil. “The resulting soil mix should be 60% sandy loam and 40% compost.” (CAHILL et al. 2011, p. 5).

The planters have an overflow (in case of very heavy rain) which connects either into the conventional drainage system of the building or preferably into another stage of stormwater management such as a pond or swale – making a stormwater chain.

Whereas the City of Portland (2020) does recommend applying a woody mulch to the top of the planters, “[…] to improve soil moisture retention, prevent weeds, and control erosion. […] Manure-based compost is prohibited. Mulch should be weed-free and applied 2 to 3 inches [5 to 8 cm] thick to fully cover the soil between plants.” (CITY OF PORTLAND, 2020, pp. 3-19). HUNT et al. (2015) advises against using organic mulches such as wood as they can block overflow pipes, and be swept around by torrents of water. Furthermore the microbial decomposing of the wood mulch will deplete the soil of nitrogen having a negative effect on the plants. The authors, therefore, recommend mulching with a 10-20 mm diameter gravel applied with a minimum depth of 100mm to suppress weeds and reduce erosion. (p. 6).

3.2 Infiltration and filtration planters

There are two types of stormwater planters: infiltration planters (as used in this trial) and filtration planters:

3.2.1 Infiltration planters

Infiltration planters allow rainwater to soak away into the ground beneath the planter, thus dramatically reducing the amount of rainwater which would otherwise reach the sewer system (figure 9). This type is unsuitable for use immediately next to buildings and can only be used when the water is free from pollutants. They are also unsuitable to use on steeply sloping ground. “Planters located on slopes greater than 10% should be designed as lined filtration planters.” (CAHILL et al. 2011, p. 7).

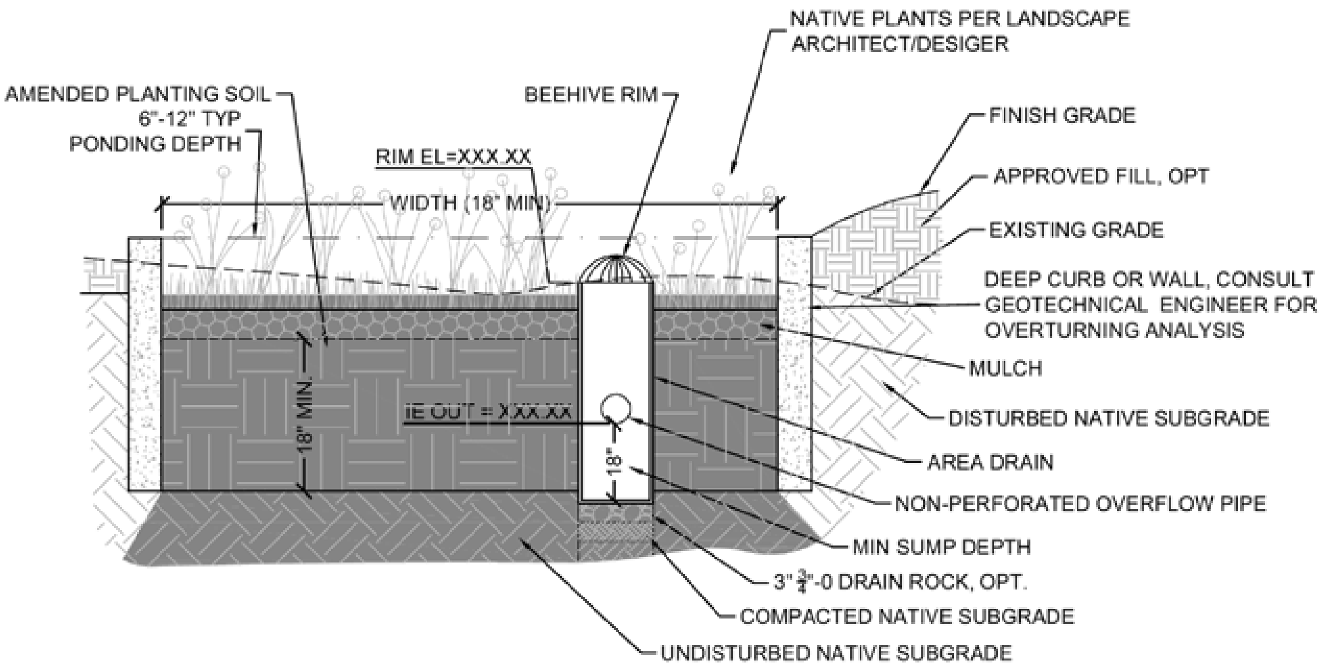

Figure 9. Diagram of an infiltration planter (Maria Cahill).

3.2.2 Filtration planters

Filtration planters are often used to remove pollutants from the water (for example, from a road, car park or industrial area) as they are lined to prevent infiltration into the ground (figure 10). “These planters allow runoff to pass through the top mulch and the middle amended soil layers before being collected in a pipe and routed to an approved disposal point.” (CAHILL et al. 2011, p. 1). It is feasible to connect the outflow pipe from such a planter to other rain garden elements (if space allows) thus making it an element in a stormwater chain. They can also be used where the infiltration of water into the ground would be problematic, for example close proximity to a building, underground car park, or the risk of contaminating ground water. (CAHILL et al. 2011, p. 2). “They are used in situations where infiltration to the underlying soil layers is unsafe or where infiltration rates of the native soils and the area available for the planter are so limited that the facility won’t drain quickly enough to ensure the survival of the plants.” (CAHILL et al. 2011, p. 1). This last point is of particular relevance to this study, if the plants used in this trial are unable to survive in the heavy clay soil used in the infiltration stormwater planters, it would be possible to re-run the trial using planters of the filtration type.

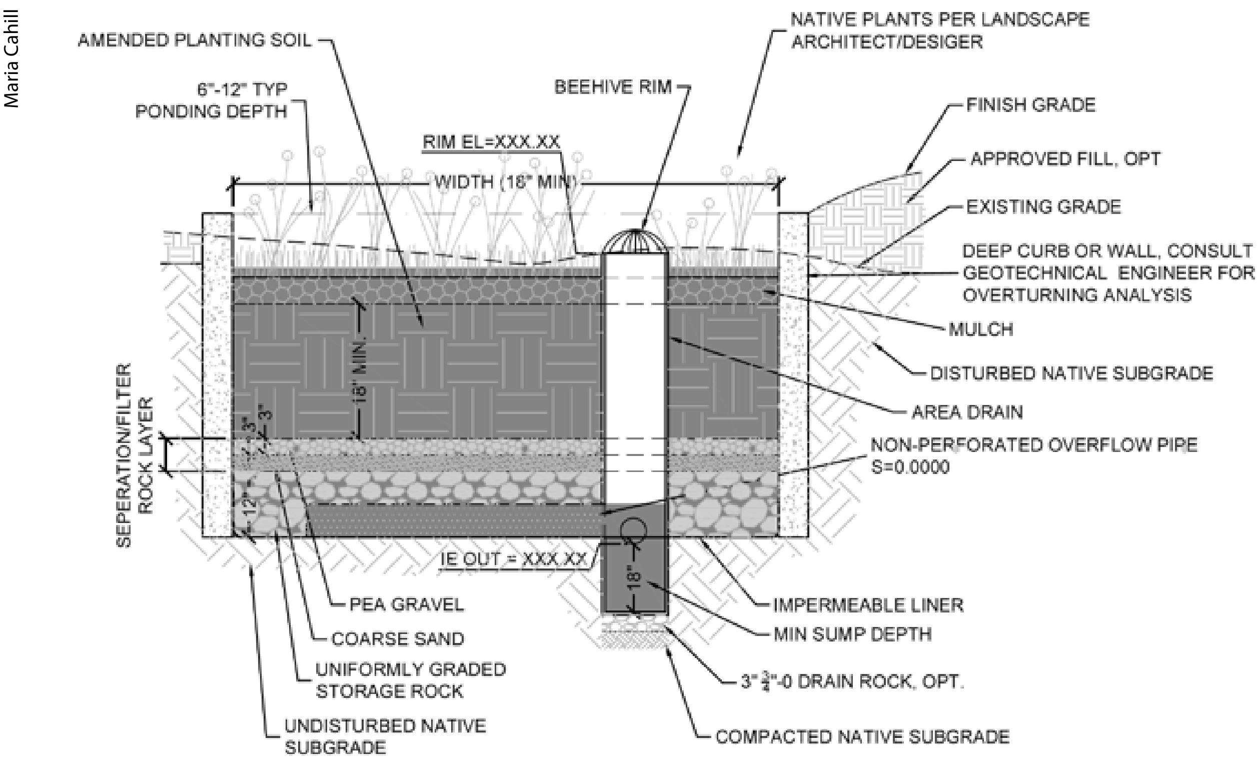

Figure 10. Diagram of a filtration planter (Maria Cahill).

3.3 Where stormwater planters can be used

Stormwater planters are particularly suited to new building projects where they can be incorporated into the architectural designs (although they can be retrofitted to existing buildings or other sealed surfaces). “Where planning authorities are actively encouraging these approaches to stormwater management there is a positive incentive for a developer to incorporate this technology.” (DUNNETT & CLAYDEN, 2007, p. 95).

As well as contributing to stormwater management they can also increase the attractiveness of a construction and increase biodiversity (figure 11). “Stormwater planters create an opportunity for the designer to improve both the visual and amenity value of a design because their environmental and engineering contribution to a project make them a necessary rather than desirable component of a development.” (DUNNETT & CLAYDEN, 2007, p. 95). In urban areas which have little or no green space their environmental benefit can be very significant.

“Stormwater planters provide opportunities for rich planting around the base of a building and, combined with a green roof, significantly reduce or eliminate excess stormwater run-off from a site.” (DUNNETT & CLAYDEN, 2007, p. 98).

Figure 11. Stormwater planter next to a building - adding biodiversity and improving the building‘s aesthetics, at the University of Innsbruck (Edward Gunn).

However, stormwater planters are one of the most expensive rain garden elements to construct. “The structural requirement of creating vertical walls makes this system one of the most expensive kinds of facilities to build. Filtration planters are more costly than infiltration planters, due to piping requirements and, since they are often constructed close to buildings, waterproofing concerns.” (CAHILL et al. 2011, pp. 9-10). They are, therefore, “[…] generally used only where sites are too constrained to build a rain garden” (CAHILL et al. 2011, p. 9) or as part of a larger stormwater chain.

3.4 Sizing the planter

Despite their high cost a significant advantage that stormwater planters have over other rain garden elements is their comparatively small size. “The main advantage planters have over rain gardens is that the structure allows more water to be stored, which reduces the footprint of the facility.” (CAHILL et al. 2011, p. 6).

It is important to calculate the necessary size of the planter in order for it to properly function. “In situations where surfaces are impervious and essentially all rainfall becomes runoff (for example, rooftops, driveways, and sidewalks, […]), the footprint of the planter typically ranges from 4% to 15% of the impervious surfaces draining to it. The footprint of infiltration planters may be increased beyond 15% if soils are poorly draining.” (CAHILL et al. 2011, p. 3). “Filtration planters can be smaller than infiltration planters because their chief purpose is cleansing runoff from small, frequent water-quality storms instead of infiltrating large quantities of runoff.” (CAHILL et al. 2011, p. 3). The exact sizing of a planter depends on several aspects: local rainfall, the volume of run off directed into the planter (impervious surfaces generating far more than, vegetated areas), the infiltration rate of the local soil and the ponding depth allowed at the top of the planter (the space at the top of the planter that can fill up after heavy rain). (CAHILL et al. 2011, p. 4).

3.5 Rain gardens in public areas

Raingardens as used in public settings, for example, alongside roads (figure 12), in car parks (figure 13), and by large sealed surfaces (figure 14), have the added complications of the water being polluted with contaminants such as oil, and rubber from vehicles, and salt which is often spread on roads and pedestrian areas during the winter. This makes the plant choices which are able to withstand these contaminants more restricted; as well as safety implications when using the water for other purposes.

Figure 12. Raingarden collecting surface run off from a road, at the University of Innsbruck (Edward Gunn).

Figure 13. Swale collecting rainwater from a car park, at the University of Innsbruck (Edward Gunn).

Figure 14. Raingarden collecting rainwater from a pedestrian area, at the University of Innsbruck (Edward Gunn).

Raingardens – and particularly stormwater planters - as used in domestic (and some public) settings have the advantage of using ‘clean’ rainwater usually taken from a roof which does not contain these contaminants (figure 15).

Figure 15. Gully (which then flows into a swale) collecting rainwater from a roof downpipe, at the University of Innsbruck (Edward Gunn).

If stormwater planters were to be constructed in public areas or adjoining public buildings they would need to meet the following Austrian Standards:

ÖNORM B 2506-1 published 2013-08-01 - Soakaways for rain-water from roof gutters and reinforced surfaces - Application, hydraulic dimensioning, construction and operation. (AUSTRIAN STANDARDS INTERNATIONAL, 2013).

ÖNORM B 2506-2 published 2012-11-15 – Soakaways for rain water from roof gutters and reinforced surfaces – Part 2: Requirements concerning the quality of soakaway rain water and requirements of dimensioning, construction and operation of purification facilities. (AUSTRIAN STANDARDS INTERNATIONAL, 2012).

4. Rainwater Management in the Last Years

Green Infrastructure and the use of raingardens have been increasing over the last few decades. Several cities in Europe, the USA and Australia in particular are increasingly incorporating stormwater management practices. “Rain gardens have become a widespread stormwater practice in the United States, and their use is poised to continue expanding as they are an aesthetically pleasing way to improve the quality of stormwater runoff.” (MORASH, et al., 2019, p. 1). However, it has not yet found widespread use with current governance being a particular barrier to its wider uptake. (DHAKAL & CHEVALIER, 2016, p. 1113).

The following section looks at two large UK based projects followed by two Austrian examples.

4.1 Grey to Green Scheme, Sheffield, UK

The UK’s largest inner city ‘Green Street’ which is also the UK’s largest retro-fit Sustainable Urban Drainage System (SUDS) is the Grey to Green Scheme in Sheffield (figure 16). The scheme was started in 2014 with phase one constructed by 2016, phase two is currently under construction. The scheme involves converting 1.6 km of former road into extensive areas of rain gardens and bioswales. The scheme is part of a wider flood risk reducing strategy to reduce and slow down surface-water runoff, which flows into the River Don. (DUNNETT, N. 2021a). “The scheme is designed primarily to capture surface water runoff from the adjacent roads and pavements, to slow down the rates of flow, to clean the water of pollutants, and to promote infiltration back down into the soil beneath and evapotranspiration back into the atmosphere.” (DUNNETT, N. 2021a). The planting areas are filled with a diverse mix of perennial planting and mulched with crushed sandstone. (DUNNETT, N. 2021a).

Figure 16. Grey to Green Scheme, Sheffield (Nigel Dunnett).

4.2 John Lewis Group, London, UK

The first street-side rain garden in London was constructed in 2015 at the head offices of the John Lewis Group. As well as the rain garden it also includes a storm water planter (figure 17). Rainwater from the roof of the portico previously flowed in a down pipe directly into the conventional drainage system. This downpipe was disconnected so that the rain water now flows through a new spout into the raised planter. It has been designed so that water can infiltrate down through the planter with any excess flowing out through outlets in the base into the rain garden. During extremely heavy rain, if the planter was to completely fill up with water it can overflow through spouts directly into the rain garden. (DUNNETT, N. 2021b).
As the storm water planter is connected to the rain garden it can be seen as the first element in a storm water chain. The rain garden is planted with a naturalistic mix of grasses and perennials to increase biodiversity and provide a low-maintenance attractive display. (DUNNETT, N. 2021b).

Figure 17. Stormwater planter in John Lewis Group Raingarden, London (Nigel Dunnett & The Landscape Agency).

4.3 DrainGarden®, Austria

In Austria a rainwater management system called DrainGarden® has been developed, which has been implemented in over 70 projects since 2014. Using a specially designed substrate, rain water and surface runoff is collected in green spaces where it can be filtered before infiltrating into the ground. A number of these projects have been installed in and around St. Pölten; these include the redevelopment of some roads, for example, Unterwagramerstrasse (figure 18), a polytechnic school (HTL St. Pölten) and the hospital in St. Pölten (Landesklinikum St. Pölten). They also have potential use along new roads built to connect newly built residential areas such as St. Pölten Eisberg. (ZENEBIO GmbH, 2021 [translated and adapted by Edward Gunn]).

Figure 18. Rain water management on Unterwagramerstrasse, St. Pölten (Edward Gunn).

4.4 Wohnpark Süßenbrunnerstraße, Vienna, Austria

In 2016 a pilot rain water management project was completed in an area containing residential blocks of flats (Wohnpark Süßenbrunnerstraße) in Vienna. The total project area is 6700m² and includes 111 flats. (GRIMM, K. 2017 [translated and adapted by Edward Gunn]). Stormwater chains have been established which include green roofs, stormwater planters and swales (figures 19 & 20) which were developed in close co-ordination between the building architects and landscape architects. (GRIMM, K. 2021 [translated and adapted by Edward Gunn]).

Figure 19. Stormwater planter collecting water from a down pipe, Wohnpark Süßenbrunnerstraße, Vienna (Karl Grimm).

Figure 20, Stormwater chain containing a stormwater planter which can overflow into a grass swale, collecting water from the building down pipe as well as from the road, Wohnpark Süßenbrunnerstraße, Vienna (Karl Grimm).

5. Plants - Theory

5.1 Plant use in rain gardens

One of the most important aspects of a stormwater planter (or any rain garden element) are the plants. Hunt et al. (2015) state:

> "Plants are essential for facilitating the effective removal of pollutants in bioretention systems, particularly nitrogen. The vegetation also maintains the soil structure of the root zone. The root system of the plants continually loosens the soil and creates macropores, which maintain the long-term infiltration capacity of bioretention systems."
> (HUNT, LORD, LOH, & SIA, 2015, p. 4)

The more densely planted a stormwater planter is the more effective it will be at filtering the water. "The interaction of soil, plants, and the beneficial microbes that concentrate on plant roots is what ultimately provides the filtration benefit of planters." (CAHILL et al. 2011, p. 5). Dense planting will also reduce weeding, as does the use of ground-covering plants which is one reason they have been included in this trial.

The City of Portland (2020) recommends the following when selecting plants for use in rain gardens:

> "The planting design must:
> - Be appropriate for site-specific conditions (soil, hydrology);
> - Minimize the need for herbicides, fertilizers, and pesticides during construction and during the life of the facility;
> - Minimize the need for mowing, pruning, and irrigation;
> - Not include plant species on the Nuisance Plants list or required Eradication List [(invasive species)...]
> - Not include plants that can damage liners due to root size or structure;"
>
> (CITY OF PORTLAND, 2020, pp. 3-21)

With specific reference to stormwater planters Dunnett & Clayden (2007) state, "Depending on size, depth and context, planters can take large shrubs and small trees, but medium to small shrubs and ground cover are more common, with at least 50 per cent of the coverage to consist of grasses or grass-like plants." (p. 95).

As there are very specific growing conditions in stormwater planters, it is important that, "Vegetation should be selected based on tolerance to flooding and ability to survive in the local climate conditions with no fertilizers, herbicides, or insecticides, and minimum to no watering after establishment." (CAHILL et al. 2011, p. 5). Chemical use should be avoided as it could leach into the local ground during infiltration or be carried off to other areas through the planter's overflow system. The use of invasive species should also be avoided as their seeds could be transported away into the wider environment during large stormwater events.

In order to test the suitability of perennial species to rain garden conditions Yuan & Dunnett (2018), conducted a simulated cyclical flooding experiment of 15 perennial species. The experiment was carried out using plants in containers inside a greenhouse in Sheffield in the UK. Subjecting the selected perennials to one and four day flooding events followed by draining periods the plants were assessed using growth measurements and a stress indicator - chlorophyll fluorescence tests. The growth measurements consisted of measuring the height and spread of the plants. (Yuan & Dunnett, 2018). This is a very similar method to the one used in this trial as described in section 6.4. They concluded that while all 15 species survived, some such as *Iris sibirica, Filipendula purpurea* and *Miscanthus sinensis* are suitable to use in a wide range of areas found in rain gardens from damp to dry while others such as *Guara lindheimeri* are better suited to drier areas. (Yuan & Dunnett, 2018). As part of their conclusions the authors state that as opposed to their experiment conditions (using plants in containers inside a greenhouse) that further research using actual rain garden situations would be beneficial. This would need to be carried out in multiple places as specific climate conditions would have an effect on the results. The trial described in this paper using stormwater planters would be an example of this for the area around St. Pölten in Austria.

As this trial is aimed at planters set in residential settings it is important that they fit into a garden environment and give a good display over the summer season. "Planters should be designed to fit into the landscape, and vegetation such as perennial flowers, ornamental grasses, and shrubs can add significant appeal to the facility. Planters can also be designed to attract beneficial insects and wildlife." (CAHILL et al. 2011, p. 5). It is for these reasons that a mixture of perennials and grasses will be used for this trial.

5.2 Plant habitats and soil moisture tolerance

Professor Richard Hansen from Weihenstephan in Germany developed a system of categorising perennials by habitat. By choosing perennials that are suited to a particular habitat they are likely to grow much more successfully. The system can also be used as an aid when planning which plants to use in a particular location. The categories can be further differentiated in terms of light levels and soil types but the main system has seven categories:

- woodland
- woodland edge
- open ground
- rock/stone
- (flower) bed
- water edge / bog
- water

(GREINER, HAGEN, & WEBER, 1995, pp. 34-35) (translated from German and adapted by Edward Gunn).

A useful addition to this system and one of particular relevance in rain gardens is to also consider the soil moisture levels in a location. These are categorised as follows with the numbers 1-4 being allocated to each category:

- Dry (1) – little moisture is present at root depth;
- Mesic (2) - the soil feels slightly damp most of the time but can sometimes be dry or wet;
- Damp/moist (3) – the ground feels damp throughout nearly the entire year;
- Wet (4) – where more water is present than the ground can absorb.

(GREINER, HAGEN, & WEBER, 1995, p. 29) (translated from German and adapted by Edward Gunn).

Table 2 in chapter 6.3 illustrates the habitat and soil moisture tolerance of the selected plants used in the trial.

If the plants trialled are successful, in the future following further research and long term trials the mixture used could be developed into a mixed planting, the theory of which is outlined in the next section (5.3).

5.3 Theory of a mixed planting

A mixed planting is the simplest way to achieve a diverse and dynamic display using perennials. A planting list is created which details the exact plant species that should be used for a particular location, as well as specifying the number of each species that should be planted per square meter. (BdS, 2021 [translated from German by Edward Gunn])

There are numerous advantages to using a mixed planting which include:

- Simplified planning and laying out – using the planting plan the ground can be easily marked out and the number of each species required easily calculated.
- The planting mix has been tested to ensure the optimum numbers of each species are used to provide the right level of competition between the plants.
- Low maintenance – which also means low maintenance costs in public areas – due to using the optimal species for the specific location.
- Mixed plantings offer more impact with varied dynamic displays with constantly changing highlights and aspects.
- An aesthetically pleasing display is achieved by using species with different appearances, spreading characteristics and heights.
- Longevity due to optimal long-term stable plant combinations. An extensive self-regulating system is established.
- The overall effect of the planting is more important than the effect or survival of any single plant.

- Short lived species dominate in the first year but then make way for perennials, creating a long-term dynamic.

- Other species can occasionally be included in the mix where they enhance the range of species used.
  (BdS, 2021 [translated from German and adapted by Edward Gunn])

The basis of a mixed planting is using the appropriate number of a tested range of species. Common design principles such as flowering succession, colour combinations, variety of spreading habitats and textures are taken into consideration as in any other planting plan. The species complement each other with different aesthetic qualities, growth strategies and spreading habitats to create an extensive self-regulating system. Location specific influences will have an effect on the performance of each species meaning the same mix will still create different displays in different locations. The care and maintenance will also influence the development of the display. (BdS, 2021 [translated from German by Edward Gunn])

Mixes usually consist of 15 to 30 species:

- Approx. 5-15% tall perennials, to give structure,

- Approx. 30-40% medium tall perennials,

- Minimum of 50% ground covering perennials,

- As well as short-lived annuals and bi-annuals, bulbs and tubers.
  (BdS, 2021 [translated from German by Edward Gunn])

6. The Trial

6.1 Location

The trial was conducted in the town of Pyhra which is situated 9km to the southeast of St. Pölten - approximately 60km west of Vienna (figure 21).

Figure 21. Map showing location of Pyhra in relation to St. Pölten and Vienna (Google maps adapted by Edward Gunn)

St. Pölten is the capital city of the state of Lower Austria. It is situated at 272m above Sea level. The climate is classified as warm and temperate, with an average annual temperature of 8.9°C. The average annual rainfall is 696 mm. (climate-data.org, 2021). The following table (1) shows the average rainfall per month in St. Pölten:

Table 1. St. Pölten average monthly rainfall (climate-data.org adapted by Edward Gunn).

January	February	March	April	May	June
31 mm	35 mm	44 mm	52 mm	76 mm	93 mm

July	August	September	October	November	December
94 mm	81 mm	55 mm	42 mm	50 mm	43mm

6.2 Construction of planters

For this trial two identical stormwater planters of the infiltration type were constructed using wood. Each measured 2.5m long, 1.25m wide with a depth of 60cm (figure 22). The inside of the planters were lined with studded plastic sheeting (figure 23) to provide a barrier between the wood and the substrate. The planters were placed on the ground a short distance away from the downpipe of a house. The bottom 10cm of each planter was filled with rounded gravel with a diameter of 32 – 50mm. This was to act as a drainage layer and prevent the bottom of the planters being permanently waterlogged. It also allows the rainwater to slowly seep into the ground beneath the planter. Each planter then had 30cm depth of substrate added. The first planter was filled with the local clay soil taken from the garden in Pyhra. As it is highly unlikely the planters would function properly with pure clay this was improved by mixing it in a ratio of 60% garden clay soil, with 20% fine sand and 20% compost (figure 24). The second planter was filled with the tree and perennial substrate used by the Council in St. Pölten (figure 25). The remaining 20cm of (ponding) depth in each planter was left so that it could temporarily fill up with water during heavy rainfall.

Figure 22. Wooden construction of the stormwater planter for the trial (Edward Gunn).

Figure 23. Studded plastic added to stormwater planters (Edward Gunn).

Figure 24. Stormwater planter with clay based substrate (Edward Gunn).

Figure 25. Stormwater planter with St. Pölten council's substrate (Edward Gunn).

Irrigation of both planters was with rain collected from a house roof. The City of Portland Stormwater Management Manual states that planters "[…] must have a sizing ratio of 6% relative to the impervious area draining to them." (CITY OF PORTLAND, 2020, pp. 3-55). The area of roof used was 47m²; this divided equally between each planter meant that each received 23.5m² worth of rain. With each planter having a surface area of 3.125m² this equates to a 13.3% planter to roof area. In order to collect the rain water and distribute it evenly to both planters the downpipe on the house was fed into a water barrel (figure 26). A pipe was connected to the water barrel which then split into two pipes which ran to each planter (figure 27). By the inlet to each planter pebbles were placed on top of the substrate to avoid erosion by the incoming flow of water (figure 28).

Figure 26. Water barrel collecting rainwater from roof via downpipe (Edward Gunn).

Figure 27. Pipes distributing rainwater equally to each planter (Edward Gunn).

Figure 28. Pebbles placed by water inlet to prevent erosion (Edward Gunn).

6.3 The plants used in the trial

In all nine species of plants were used including grasses for structure, perennials for seasonal colour and ground covering plants to reduce weeding. The same numbers of each of the species were planted in the same positions in each planter (figures 29 & 30).

Figure 29. Plants in clay based substrate shortly after planting (Edward Gunn).

Figure 30. Plants in St. Pölten substrate shortly after planting (Edward Gunn).

As the colours of the Lower Austria flag are blue and yellow, these two colours were selected for the colour scheme with a little white added. The species were all chosen for their suitability to the specific growing conditions seen in the trial, with the hope that they would be successful. “The plants chosen should be tolerant of periodic wet conditions, but are not water plants because the planters do not remain permanently wet.” (DUNNETT & CLAYDEN, 2007, p. 96). In fact for this trial it was more important to choose plants that can withstand some drought conditions rather than plants that tolerate boggy conditions as particularly in the last summers there have often been long dry periods in between rain. Table 2 shows the habitats and soil moisture tolerance of the selected species as based on the category system described in Chapter 5.2.

Table 2. Habitat and soil moisture tolerance of the selected plant species used in the trial (Staudengärtnerei Gaißmayer and Staudengärtnerei Kirschenlohr translated and adapted by Edward Gunn).

Plants	**Habitat**							**Soil moisture tolerance**			
	Woodland	Woodland edge	Open ground	Rock/Stone	(flower) Bed	Water edge / Bog	Water	Dry (1)	Mesic (2)	Damp/ moist (3)	Wet (4)
Alchemilla sericata 'Gold Strike'		*	*		*				*	*	
Aquilegia alpina		*	*						*	*	
Calamagrostis brachytricha		*	*		*				*		
Geranium x cultorum `Sabani Blue`		*	*		*				*		
Gypsophila repens				*				*	*		
Hemerocallis x cultorum `Stella d'Oro`		*	*		*				*		
Inula ensifolia `Compacta`			*	*				*	*		
Pennisetum alopecuroides `Hameln'			*						*		
Veronica teucrium `Knallblau`			*					*	*		

As can been seen in the table all of the chosen species are suited to Mesic (category 2) conditions, with three of the species also tolerating drier conditions and two species damper conditions. None of the selected species are categorised for wet (category 4) conditions.

Furthermore, it was important to select plants for the trial that not only do well in rain gardens but have also been proven to perform well in the local climate. Therefore, some of the choices were based on literature research such as recommendations made by Agnes Renkin and Nora Heger in their 2018 Master thesis 'Regenwassermanagement. Eignung von Pflanzenarten und Pflanzkonzepten für Sickermulden in Wiener Wohnhausanlagen' - which looked at plant use in integrative rainwater management facilities in residential complexes in Vienna.
Further choices were based on recommendations from a discussion with Robert Wotapek the head of the gardening department at St. Pölten council. The choices were then further refined based on creating the yellow and blue colour scheme and ensuring a mix of tall, medium and low growing plants to create an attractive display.

This resulted in the following nine species being chosen for the trial:

Alchemilla sericata ‘Gold Strike’

Common name: Lady’s Mantle

Family: Rosaceae

Origin: Mediterranean to Caucasus

Description: Grows to a height of 35cm with yellow green flowers from June to August. “It forms neat, compact mounds of grey-green leaves, topped with upright sprays of lime-green flowers in late spring and early summer.” (Gardenersworld.com, 2021)

Figure 31. *Alchemilla Sericata* 'Gold Strike' (Edward Gunn).

Aquilegia alpina.

Common name: Alpina Columbine

Family: Ranunculaceae

Origin: Alps, Northern Italy

Description: Grows to a height of 50cm with cobalt blue flowers from May to June. “*Aquilegia* derives from the Latin for “eagle,” and refers to the five long, hollow spurs sweeping back from the flower’s face, supposedly resembling the talons of a bird of prey; columbine (Latin for “dove”) offers a gentler vision-turn the flower over and look for the resemblance to five

Figure 32. *Aquilegia alpina* (Edward Gunn).

doves perched around a fountain. In addition to the flowers, aquilegias offer daintily divided or lobed, rich green or blue-green foliage.” (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 63) “Easy to grow, columbines thrive in most soils as long as they drain well. To promote the best growth and bloom, water regularly but avoid soaking; overwatering is generally fatal.” (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 63) “Well-drained soil is essential; prefers partial shade in warmer, sunnier regions. Reseeds freely in hospitable locations.” (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 64)

Calamagrostis brachytricha

Common name: Korean feather-reed grass

Family: Poaceae

Origin: Central to East Asia

Description: Has clump forming foliage, grows to a height of 100cm and flowers from August to September. The flowers “[…] are tinged a lovely red-violet when they emerge, maturing to a wheat color in the autumn.” (DISABATO-AUST, 2008, p. 56).

“Tolerant of a wide range of soils including heavy clay in part shade or full sun, the plants benefit from afternoon shade in hot climates.” (DISABATO-AUST, 2008, p. 56)

Figure 33. *Calamagrostis brachytricha* *(Edward Gunn).*

Geranium x cultorum 'Sabani Blue'

Common name: Cranesbill

Family: Geraniaceae

Origin: Southern Africa

(This variety was bred in the UK)

Description: Grows to a height of 40cm with large blue flowers with deep blue veining from May to June. Has mounds of foliage and makes excellent groundcover. If deadheaded after flowering it often produces a second flush of flowers. (RHS, 2021a)

Figure 34. *Geranium x cultorum* 'Sabani blue' (Edward Gunn).

Gypsophila repens

Common name: Creeping baby's breath; Creeping gypsophila

Family: Caryophyllaceae

Origin: Central and Southern Europe

Description: Grows to a height of 20cm with white flowers from May to July. "Gypsophila means "gypsum-" or "chalk loving," and most members of this genus prefer an alkaline soil." (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 199) "[…] a semi-evergreen perennial […] forming a mat of narrow foliage, with open

Figure 35. *Gypsophila repens* (Edward Gunn).

panicles of small, starry, white or pale lilac flowers 10mm in width over a long period in summer" (RHS, 2021b).

"Drought tolerant, but regular irrigation during dry spells in spring and early summer is critical to the flower quality." (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 200).

Hemerocallis x cultorum 'Stella d'Oro'

Common name: Daylily

Family name: Hemerocallidaceae

Origin: Asia and Central Europe

Description: Grows to a height of 40cm with deep yellow flowers from May to October. "*Hemerocallis* foliage is strap shaped, long and narrow. Leafless stems (scapes) carry the flowers; they have parts in threes." (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 213)

"Average garden soil suits most daylilies, but they will tolerate poor, well-drained soils that retain moisture; drought tolerant when established." (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 214)

Figure 36. *Hemerocallis x cultorum* 'Stella d'Oro' (Edward Gunn).

Inula ensifolia ‘Compacta’

Common name: Swordleaf inula

Family: Asteraceae

Origin: Caucasus region of Europe

Description: Grows to a height of 20cm with yellow flowers from July to August. “This easy, compact perennial branches freely, and is topped with solitary or groups of slender rayed, 1- to 2-in. [2.5-5cm], orange-yellow daisies. Coarse willow-like leaves are sessile, alternate, and parallel veined, hence “*ensifolia*,” which means “leaves like swords.” Their bloom time may last six weeks or so; excellent cut flowers.” (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 233).

Figure 37*. Inula ensifolia* 'Compacta' (Edward Gunn).

Pennisetum alopecuroides ‘Hameln’

Common name: Chinese fountain grass;
Ornamental fountain grass

Family: Poaceae

Origin: “This sun-loving ornamental grass is native to North Africa, Saudi Arabia, Turkey, Iran and the Caucasus to northwest India, growing in open rocky areas, screes and hillsides.” (BLOOM, 2010, p. 160).

Figure 38*. Pennisetum alopecuroides* ‘Hameln‘ (Edward Gunn).

Description: A clump-forming perennial grass which grows to a height of 60-75cm and flowers from July to October. The leaves are arching and linear while the bristly cylindrical panicle flowers have a green tinge before changing to creamy white with a purple tinge. (RHS, 2021c)

Maintenance: "The flowers and foliage tend to collapse by midwinter, but can be left until it looks scruffy or to early spring before cutting back. It can be raised from seed, and established clumps can be lifted and divided in spring for replanting." (BLOOM, 2010, p. 160)

Veronica teucrium 'Knallblau'

Common name: Hungarian speedwell;
Broadleaf speedwell

Family: Plantaginaceae

Origin: Southern Europe

Description: Grows to a height of 30cm with blue flowers from May to July. "Low mats of oblong, hairy, grayish green, 3-in [7.5cm]. leaves; stem leaves mostly sessile. Terminal, 4- to 6-in [10-15cm]. racemes of saucer-shaped flowers." (ROGERS CLAUSEN & CHRISTOPHER, 2014, p. 399).

Figure 39. *Veronica teucrium* 'Knallblau' (Edward Gunn).

6.4 Monitoring method

The trial commenced in spring 2019 and continued for one growing season until the autumn. The monitoring was split into two main types – those that could be physically measured and those that were subjective.

The amount of rainfall during this period was recorded on a daily basis. A weekly survey (including photographs) was carried out to determine the status of each stormwater planter. This included noting: which plants were currently in flower; the average height and spread of each plant species; the overall attractiveness of the display; if the plants were showing signs of stress from drought or too much water; if any weeding or other maintenance was required; if the planters required additional watering due to a long dry period.

The amount of daily rainfall could be physically measured using a rain gauge; likewise the height and spread of the plants could also be physically measured using a tape measure and noted. Other assessment criteria such as the overall attractiveness of the display cannot as such be physically measured and are subjective. To overcome this, a survey was used which was adapted from a monitoring survey used by a German based association which studies perennials (Arbeitskreis Staudensichtung im Bund deutscher Staudengärtner). The relevant criteria of the German survey were adapted to fit the aims of this trial and to provide answers to the research questions.

The two planters used in the trial were then visually assessed using this adapted survey and given a score based on a scale from 1 to 9;

1 = very poor,
3 = poor,
5 = acceptable,
7 = good,
9 = very good.

The criteria that were assessed using this method were:

- The aesthetic impact of the whole display (overall impression) – close up
- The aesthetic impact of the whole display (overall impression) - as seen from a distance
- Amount of weeds present
- Area of ground covered (by spread of plants)
- Vitality of the plants

(Arbeitskreis Staudensichtung im Bund deutscher Staudengärtner, [translated from German and adapted by Edward Gunn])

The growth development of the plants (height and spread) was not assessed using this method as it was physically measured, the results of which can be seen in the graphs in chapter 7.2.

7. Results and Analysis

7.1 As seen over time

May

In May the *Aquilegia alpina* and the *Veronica teucrium* ‘Knallblau’ were both flowering giving vivid blue highlights to the planting scheme.

Figure 40. Clay based substrate planter in May (Edward Gunn).

Figure 41. St. Pölten substrate planter in May (Edward Gunn).

June

In early June the *Alchemilla sericata* ‘Gold Strike’ and the *Gypsophila repens* began flowering in the clay based substrate but not in the St. Pölten substrate. During these first couple of months the overall aesthetics of the display were limited as the plants were still small and establishing themselves. A lot of bare ground was visible between the plants which detracted from the appearance. However, the species so far mentioned that did flower added some highlights to the planting scheme.

Figure 42. Clay based substrate planter in June (Edward Gunn).

Figure 43. St. Pölten substrate planter in June (Edward Gunn).

Due to the relative small amount of rainfall throughout June small cracks started to appear in the St. Pölten substrate whereas very large cracks formed in the clay based substrate. By the middle of June these cracks had widened to up to 3cm across and 10cm deep in the clay based substrate, as can be seen in the following photos:

Figure 44. Wide cracks in clay based substrate (Edward Gunn).

Figure 45. Deep cracks in clay based substrate (Edward Gunn).

By the end of June there were some further differences between the two trial beds. The plants of the St. Pölten substrate bed were generally more yellow looking and less green than those in the clay based substrate. Two of the *Aquilegia alpina* plants in the St. Pölten substrate had died and the rest looked in very poor condition. Although the plants in the clay based substrate had so far all survived it was clear that both planters were showing signs of water stress. As the plants were not yet fully established it was decided at this point to artificially irrigate the two beds to ensure the survival of all of the plant species and to enable the trial to continue. Consequently both planters were irrigated for five minutes each using a garden hose with a spray nozzle attached. It is likely that if the plants were fully established it would not have been necessary to water them. A number of weeds had also started to get established in both planters by this time so both were also weeded. This would also help the plants in the trial by removing competition for water from the weeds.
At this time the *Alchemilla sericata* 'Gold Strike' was in full flower, the *Inula ensifolia* 'Compacta' had just started to begin flowering. The *Aquilegia alpina* had finished flowering and had developed ripe seed heads. The *Veronica teucrium* 'Knallblau' had also finished flowering. The *Gypsophila repens* was still flowering in the clay based substrate although much less profusely. It had begun to flower in the St. Pölten substrate. Flower buds were forming on the *Hemerocallis x cultorum* 'Stella d'Oro'.

July

By the end of July the *Alchemilla sericata* 'Gold Strike' had finished flowering, but the *Inula ensifolia* 'Compacta' was now in full flower as were the *Hemerocallis x cultorum* 'Stella d'Oro'. This meant the colour scheme of the planters had now swung completely from blue in May and early June to yellow. The *Gypsophila repens* was now finishing to flower in the clay based substrate but was in full flower in the St. Pölten substrate. The overall appearance of both planters revealed that the plants in the clay based substrate still looked greener, while those in the St. Pölten substrate looked more yellow. There were still large cracks in the clay based substrate. Again a number of weeds had established in both planters, so both were again weeded.

Figure 46. Clay based substrate planter in July (Edward Gunn).

Figure 47. St. Pölten substrate planter in July (Edward Gunn).

August

In August the *Pennisetum alopecuroides* ‘Hameln’ began flowering in both planters adding a new dynamic. The flowering of the *Hemerocallis x cultorum* ‘Stella d’Oro’ continued throughout the month but came to an end in both planters by the end of August. The *Inula ensifolia* ‘Compacta’ finished flowering in the clay based substrate but continued in the St Pölten substrate. The *Gypsophila repens* also continued flowering in the St. Pölten substrate only. By the middle of August the plants had reached sufficient size to significantly enhance the aesthetics of the display. There was much less bare soil and the planters looked fuller, with many of the plants now significantly taller than the sides of the planter; this improved the overall impression of the display as viewed from further away.

Figure 48. Clay based substrate planter in August (Edward Gunn).

Figure 49. St. Pölten substrate planter in August (Edward Gunn).

September and October

Throughout September and into October the *Pennisetum alopecuroides* 'Hameln' continued flowering in both planters. The *Calamagrostis b*rachytricha although increasing their spread quite significantly during the trial never actually flowered. Into October their leaves started to go yellow. The *Inula ensifolia* 'Compacta' and the *Gypsophila repens* also continued flowering in the St. Pölten substrate only but with decreasing vigour and only one or two flowers to be seen by mid-October. In the clay based substrate the *Inula ensifolia* 'Compacta' plants had largely withered away. By this time the *Gypsophila repens* had increased their spread so much that the individual plants had now merged into one 'carpet'. This meant there was now hardly any bare substrate to see in either planter, and should significantly help with weed control and water evaporation loss in the future. By the end of the trial the ground cover in the clay based substrate planter was very nearly 100%, in the St. Pölten substrate it was about 90%. Weeds were again present in both planters by mid-October. As expected at this time of year the peak of the planter's aesthetic display had passed. Close up the fact that no bare ground was to be seen and the plants were now growing together as one mixed planting did give a good overall impression.

Figure 50. Clay based substrate planter in October (Edward Gunn).

Figure 51. St. Pölten substrate planter in October (Edward Gunn).

Winter Aspect

Although the trial was concluded at the end of October the following photos were taken in December and show the winter aspect of the planters. The seed heads of the *Pennisetum alopecuroides* 'Hameln' still give some interest above the frosted foliage of the other perennials.

Figure 52. Winter aspect of clay based substrate planter (Edward Gunn).

Figure 53. Winter aspect of St. Pölten substrate planter (Edward Gunn).

7.2 Assessment of each plant species

Alchemilla sericata 'Gold Strike'

Table 3. *Alchemilla sericata* 'Gold Strike' flowering calendar (Edward Gunn).

Alchemilla sericata 'Gold Strike'	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

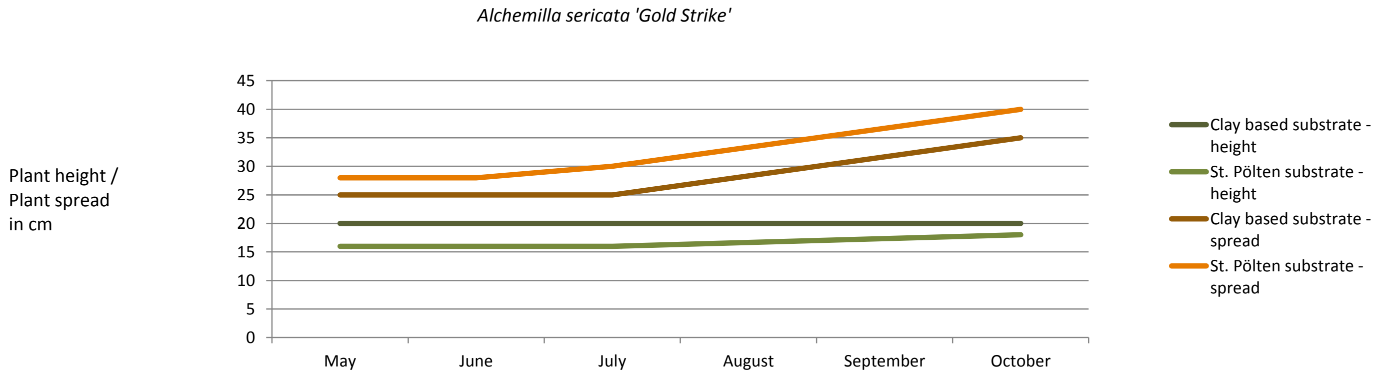

Figure 54. *Alchemilla sericata* 'Gold Strike' growth rates (Edward Gunn).

These flowered throughout June and the first half of July. The flowering in the clay based substrate started more strongly than in the St. Pölten substrate. The growth rates show that the height of the plants never really altered throughout the trial, however they did spread out quite significantly from July onwards once the plants had established themselves. The growth rates of both substrate types were very similar, indicating that the plants are able to grow well in either substrate.

Aquilegia alpina

Table 4. *Aquilegia alpina* flowering calendar (Edward Gunn).

Aquilegia alpina	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

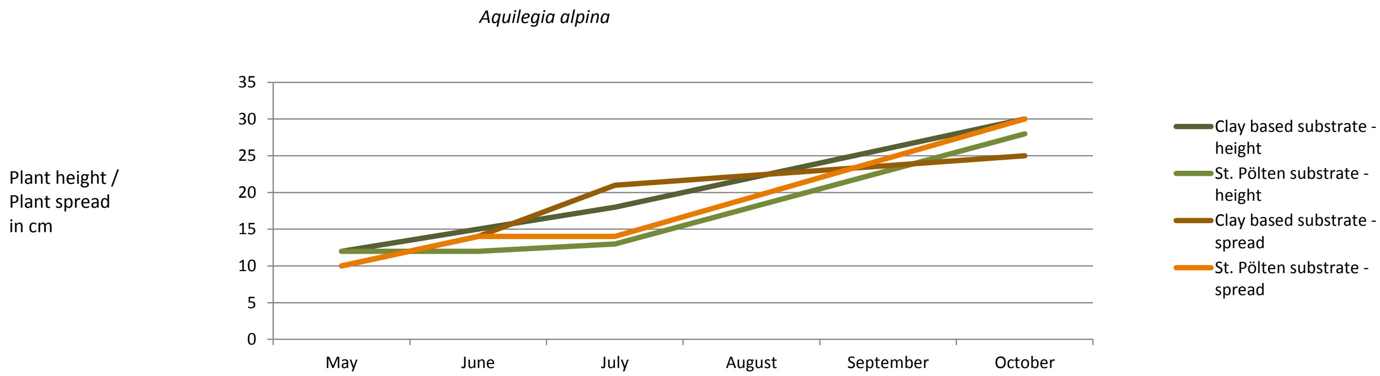

Figure 55. *Aquilegia alpina* growth rates (Edward Gunn).

The *Aquilegia alpina* flowered from the beginning of the trial in May through until the middle of June. In the early part of the trial they certainly struggled in the St. Pölten substrate with two plants dying and the rest looking in poor condition. They fared much better in the clay based substrate. The graph shows that their growth in terms of height and spread was much stronger in the clay based substrate in the first few months of the trial. By the end of the trial the plants had reached similar sizes and were well established in both substrates.

Calamagrostis brachytricha

Table 5. *Calamagrostis b*rachytricha flowering calendar (Edward Gunn).

***Calamagrostis* brachytricha**	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

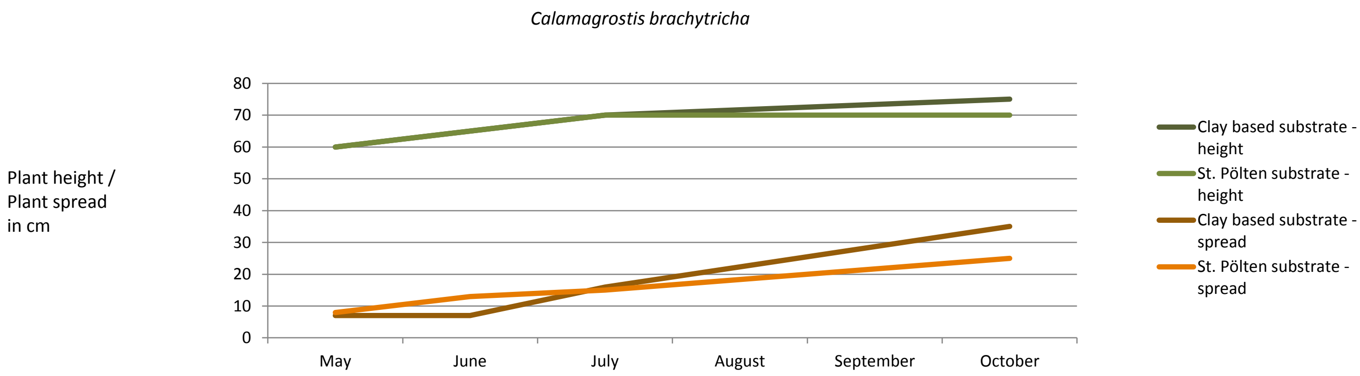

Figure 56. *Calamagrostis b*rachytricha growth rates (Edward Gunn).

*Calamagrostis b*rachytricha did increase their spread quite significantly during the trial, but only increased their height a little. The growth rates were slightly higher in the clay based substrate than in the St. Pölten substrate. By mid-October the plants were starting to go yellow.

Geranium x cultorum ‘Sabani Blue’

Table 6. *Geranium x cultorum* 'Sabani Blue' flowering calendar (Edward Gunn).

Geranium x cultorum `Sabani Blue`	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

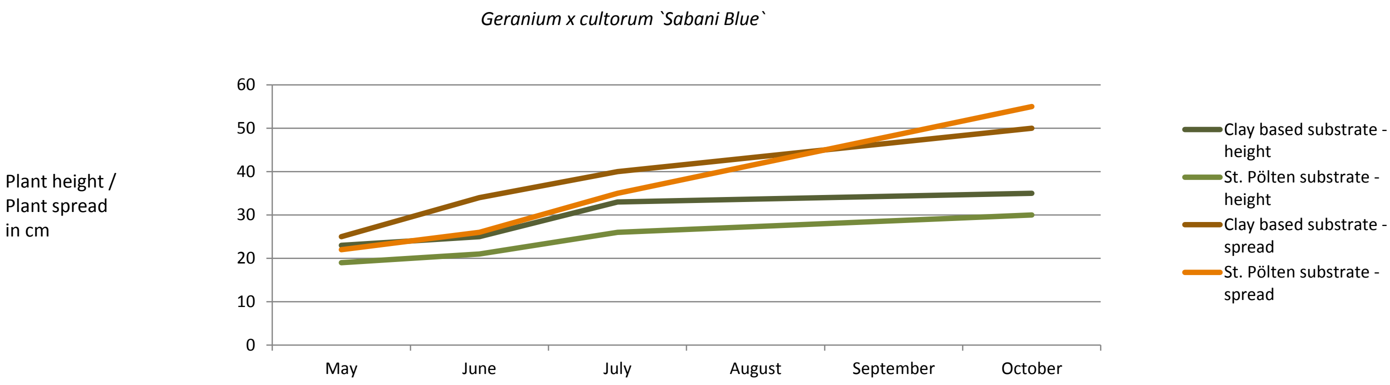

Figure 57. *Geranium x cultorum* 'Sabani Blue' growth rates (Edward Gunn).

Geranium x cultorum ‘Sabani Blue’ failed to flower in either substrate during the trial. The growth rates show that during the trial the spread of the plants doubled, while the height of the plants increased a little. The initial growth appears faster in the clay based substrate indicating that the plants can establish themselves quicker in this substrate than in the St. Pölten substrate.

Gypsophila repens

Table 7. *Gypsophila repens* flowering calendar (Edward Gunn).

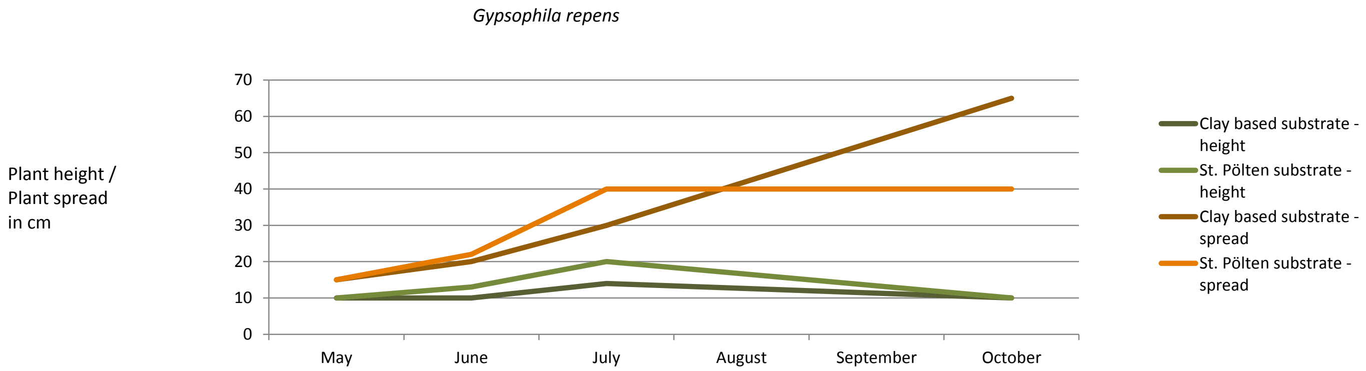

Figure 58. *Gypsophila repens* growth rates (Edward Gunn).

Gypsophila repens began flowering much earlier in the clay based substrate flowering steadily for two months. Although it started a month later in the St. Pölten substrate it then went on until the end of the trial (full flowering finished in September with just a little bit of flower to be seen towards the end of the trial). As a ground covering perennial the height growth is largely not relevant. The spread of the plants showed enormous growth over the trial period especially in the clay based substrate where the plants more than quadrupled in size. The spread in the St. Pölten substrate was considerably less (approximately two and a half times the original size). By the end of the trial the individual *Gypsophila repens* plants had knitted together to form one continuous mat across the surface of the substrate in both planters. The ground coverage was approximately 90% in the St. Pölten substrate but close to 100% in the clay based substrate.

Hemerocallis x cultorum ‘Stella d’Oro’

Table 8. *Hemerocallis x cultorum* 'Stella d'Oro' flowering calendar (Edward Gunn).

Hemerocallis x cultorum `Stella d'Oro`	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

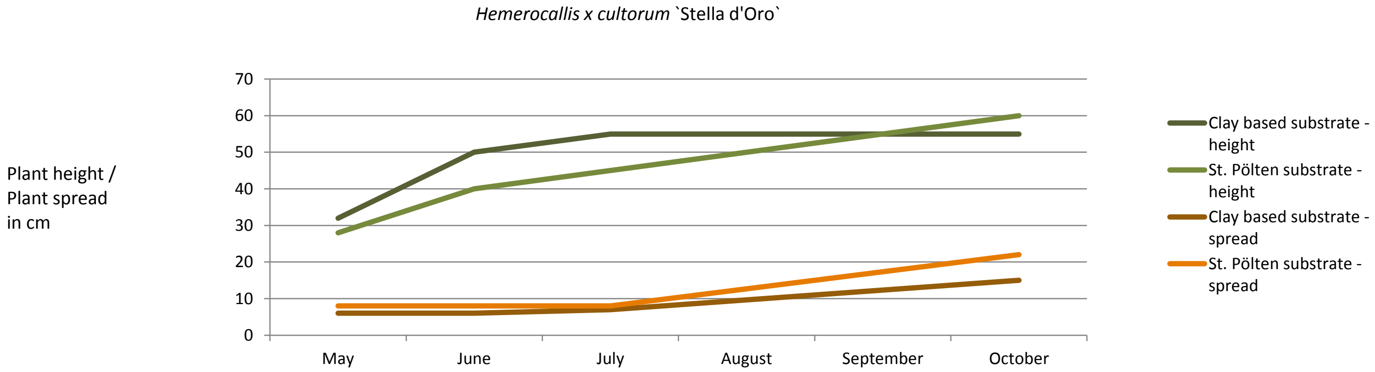

Figure 59. *Hemerocallis x cultorum* 'Stella d'Oro' growth rates (Edward Gunn).

Hemerocallis x cultorum ‘Stella d’Oro’ flowered well from mid-July until the end of August. Generally only a few flowers per planter were to be seen at any one time. The plants grew well in both substrates nearly doubling in height and spread during the trial period.

Inula ensifolia

Table 9. *Inula ensifolia* flowering calendar (Edward Gunn).

***Inula ensifolia* `Compacta`**	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

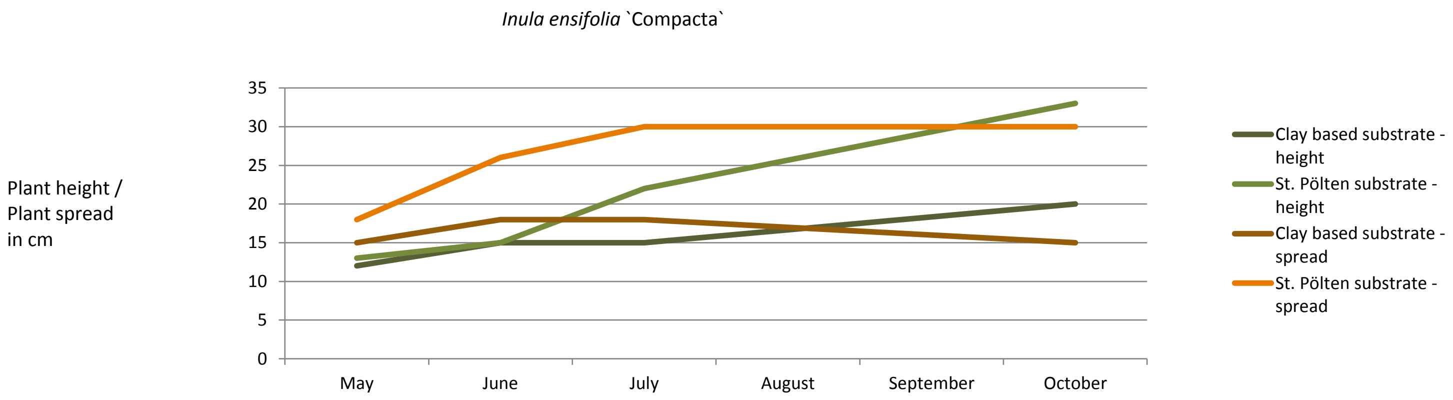

Figure 60. *Inula ensifolia* growth rates (Edward Gunn).

Inula ensifolia started flowering in both planters in early July. In the clay based substrate the flowering continued until mid-August whereas in the St. Pölten substrate it continued until mid-October. The growth rate graph also shows a considerable difference between the two substrates. Both in terms of height and spread, the plants in the St. Pölten substrate grew considerably more (nearly doubling their spread and nearly tripling their initial height) than in the clay based substrate. By the end of the trial the plants in the clay based substrate had largely all disappeared.

Pennisetum alopecuroides ‘Hameln’

Table 10. *Pennisetum alopecuroides* 'Hameln' flowering calendar (Edward Gunn).

Pennisetum alopecuroides `Hameln'	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

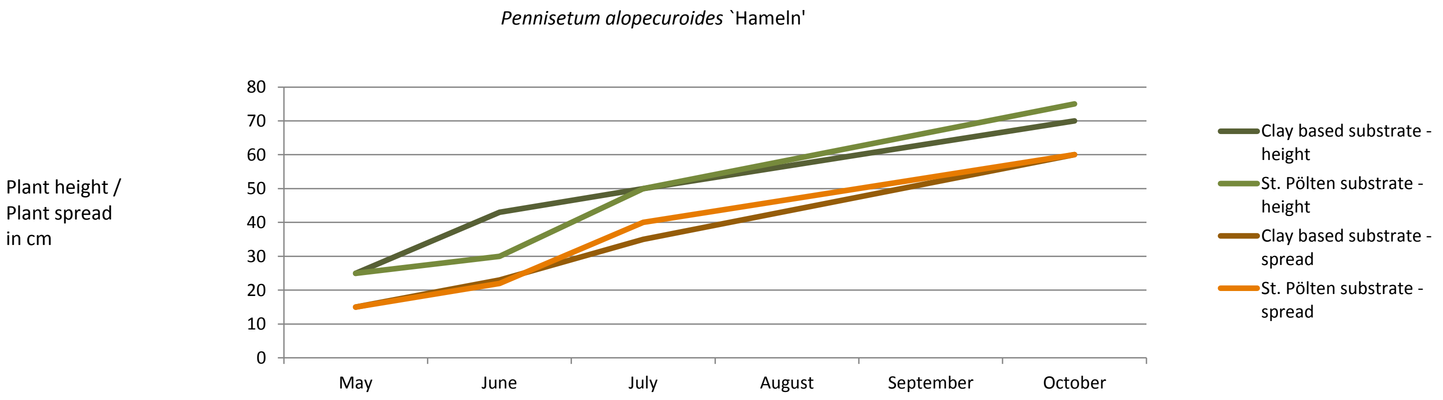

Figure 61. *Pennisetum alopecuroides* 'Hameln' growth rates (Edward Gunn).

Pennisetum alopecuroides ‘Hameln’ began flowering at the beginning of August in both planters and continued until the end of the trial. The growth rates of height and spread were extremely similar across both planters. The only slight difference as noted with some other species was that the height of the plants in the clay based substrate began to increase sooner than it did with the plants in the St. Pölten substrate.

Veronica teucrium ‘Knallblau’

Table 11. *Veronica teucrium* 'Knallblau' flowering calendar (Edward Gunn).

Veronica teucrium `Knallblau`	May	June	July	August	September	October
Producer's stated flowering time						
Clay based substrate						
St. Pölten substrate						

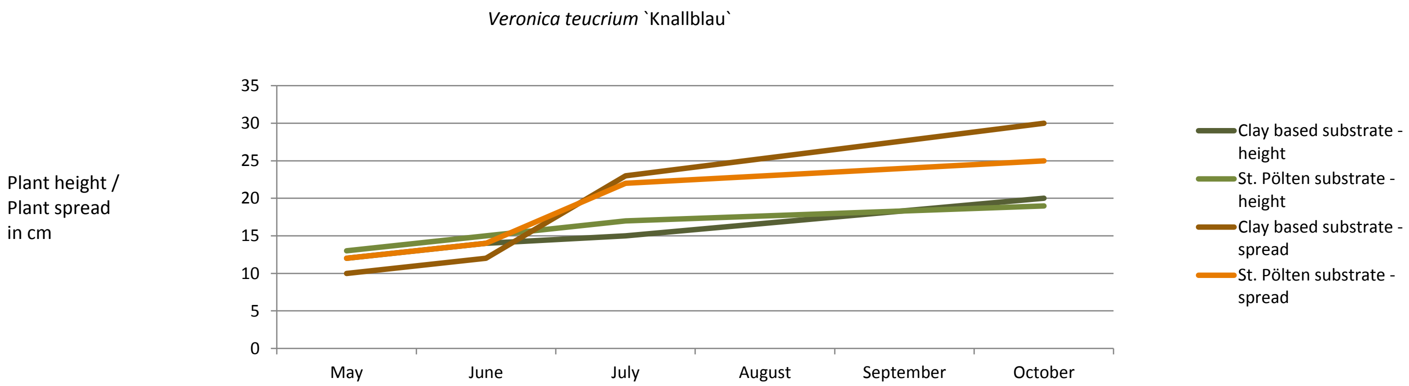

Figure 62. *Veronica teucrium* ‘Knallblau' growth rates (Edward Gunn).

Veronica teucrium ‘Knallblau’ had the shortest flowering time (not including the two species that failed to flower at all) of the species used in the trial, at just one month from mid-May to mid-June. By the end of the trial the plants in the clay based substrate had reached their full height, as well as increasing their spread. The growth rates between the two planters was extremely similar but with the plants in the St. Pölten based substrate not quite reaching their full height by the end of the trial.

7.3 Rainfall graphs

The following graphs show the daily rainfall (mm/m²) which was recorded for the duration of the trial:

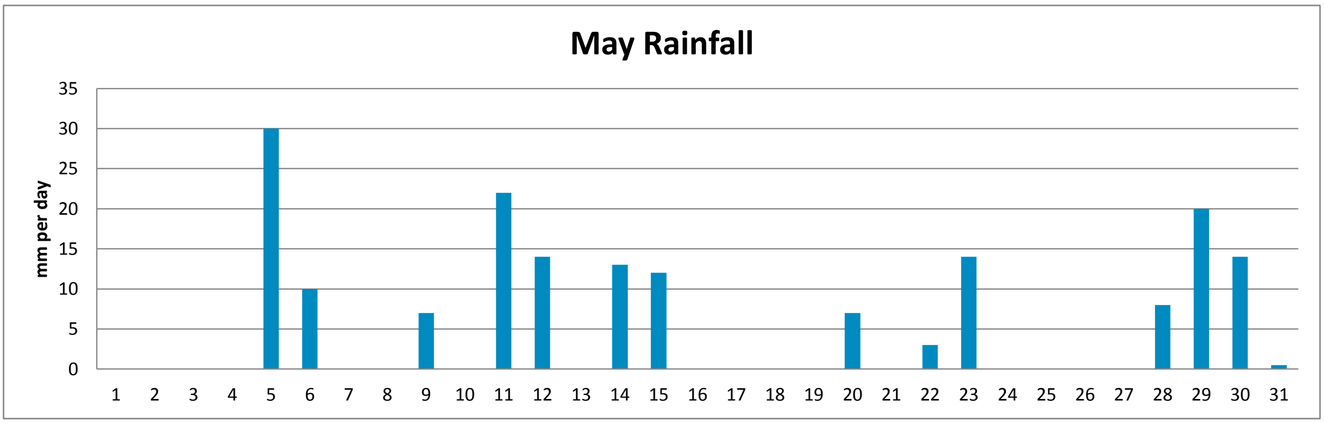

Figure 63. May rainfall (Edward Gunn).

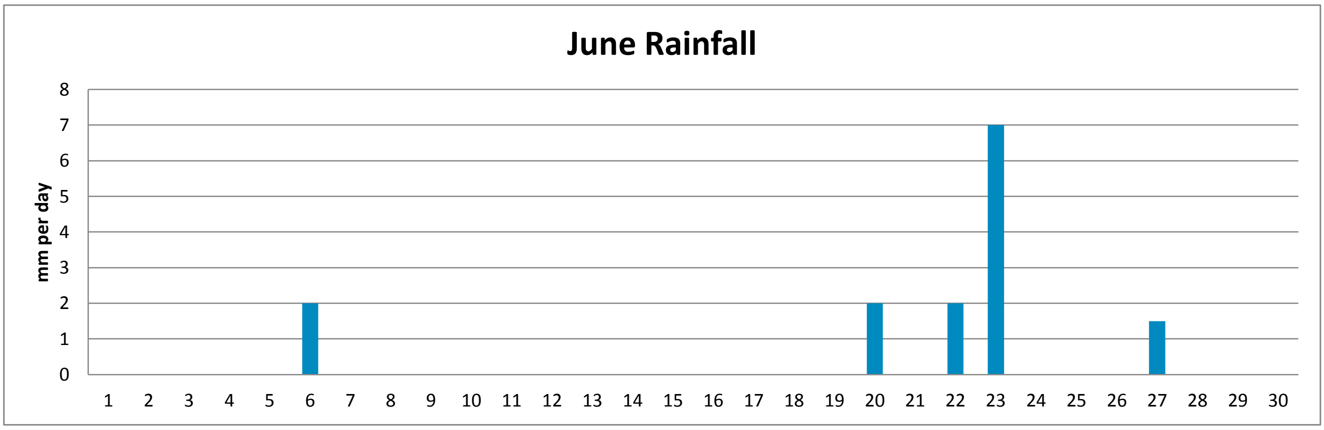

Figure 64. June rainfall (Edward Gunn).

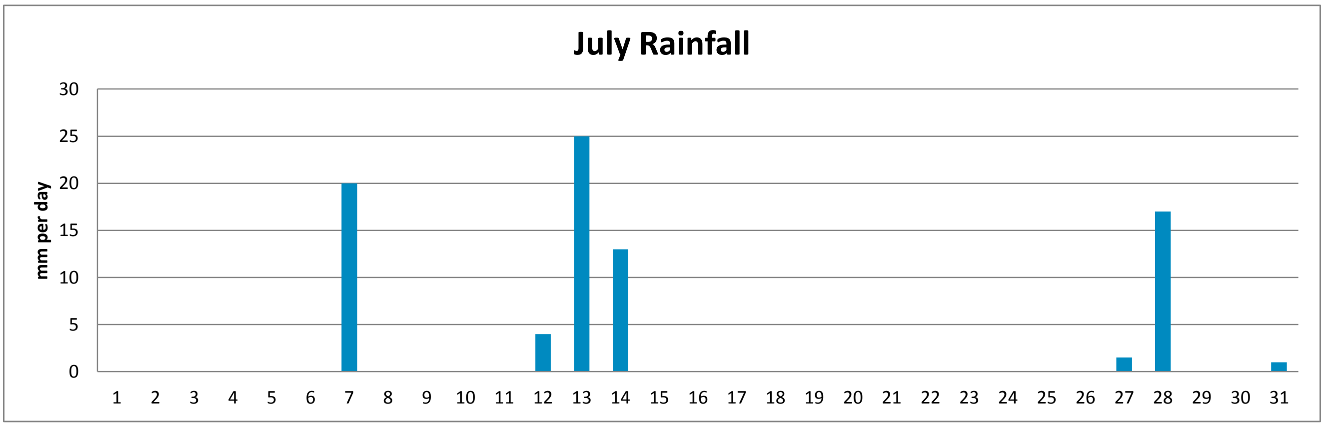

Figure 65. July rainfall (Edward Gunn).

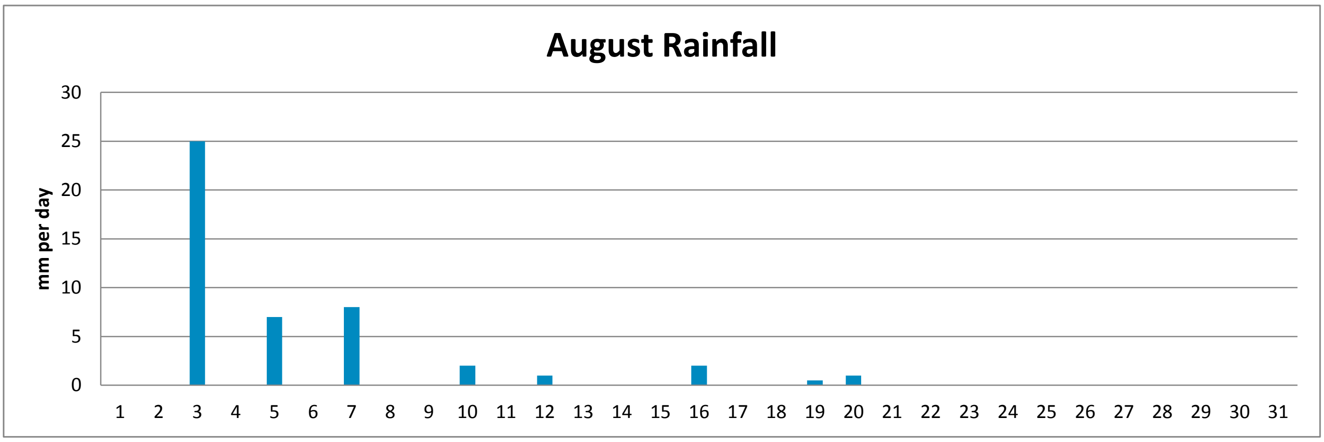

Figure 66. August rainfall (Edward Gunn).

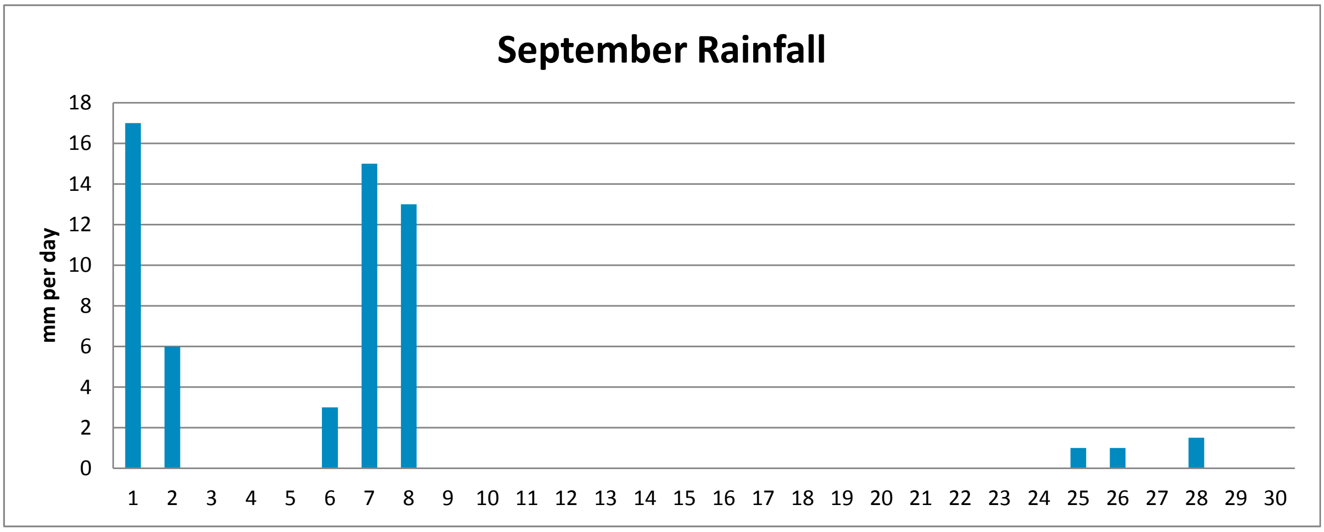

Figure 67. September rainfall (Edward Gunn).

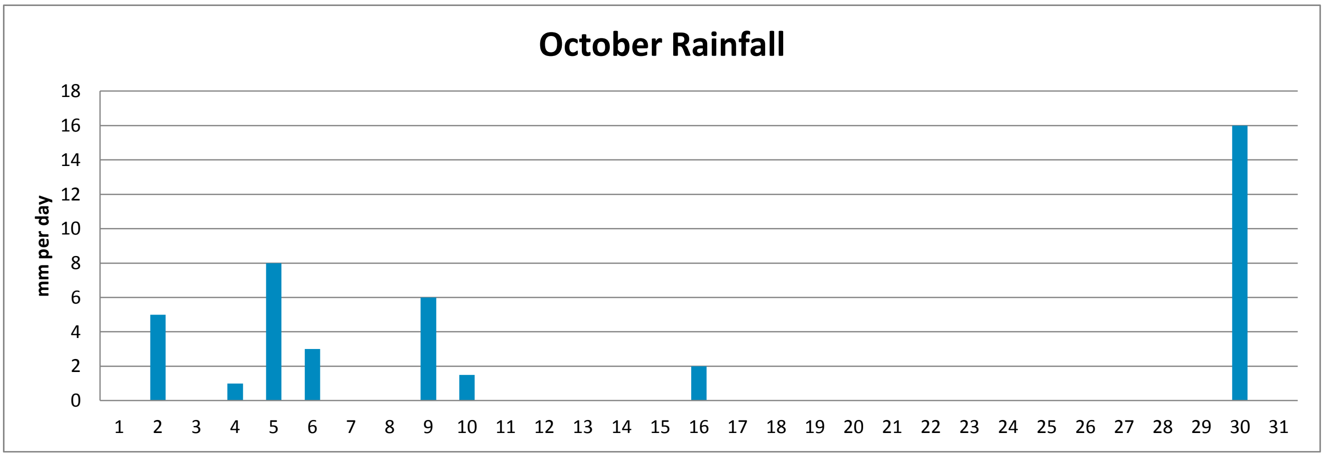

Figure 68. October rainfall (Edward Gunn).

By far the wettest month during the trial was May with 174.5mm of rain; this is nearly 100mm more than the average for this month. The driest month was June with just 14.5mm, which is approximately six times less than the monthly average of 93mm. August was also a lot drier than average with just over half the average rainfall. The other months in the trial (July, September, and October) saw close to the average expected rainfall for these months. The extremely dry month of June caused considerable stress to the plants as they were only just establishing themselves at this time. This is why as previously mentioned the beds were artificially watered at this time to keep the plants alive and the trial running. After this time the beds were not artificially watered again and the plants only received water when it rained.

During the period of the trial a total of 460mm of rain was recorded. This multiplied by the $47m^2$ of roof space used to collect the rain means a total of 21,620mm ($21.62m^3$) was diverted through the two planters and did not enter the conventional drainage system. If all of this water was used for irrigation in the garden or was collected and used for other purposes the following saving can be calculated: At the current water rate of €1.70 per m^3 in Pyhra this equates to a saving of €36.75 over the period of the trial. If the planter was used all year round then based on the average annual rainfall of 696mm the amount of water prevented from reaching the conventional drainage system would be $32.71m^3$ and the potential saving of this water would be €55.61.

8. Discussion and Recommendations

8.1 Stormwater planters

As mentioned in section 3.1 it is important that the rain water flows through the planters relatively quickly to avoid the soil becoming waterlogged and detrimental anaerobic conditions forming. This was of particular interest due to the use of heavy clay soil in this trial which is renowned for being poor draining and becoming waterlogged. By mixing the clay with sand and compost (in a ratio of 60% clay / 20% sand / 20% compost) the resulting substrate was free draining and waterlogging did not occur. In fact both the clay based substrate and St. Pölten council substrate were very free draining to the extent that no ponding occurred at the top of the planters even during heavy rain storms. Instead water was often seen escaping from the bottom of the planters during heavy rain. This was likely due to the 10cm deep gravel drainage layer at the bottom of the planters combined with the fact that the underlying ground on which the planters sat was unimproved heavy clay soil which has a slow absorption rate. This should be taken into consideration when siting such planters so that excess water flowing out of the planters does not become a nuisance to nearby buildings or other areas. This problem could also be overcome by using filtration planters instead of infiltration planters. As a filtration planter is sealed at the bottom to prevent water from escaping, it is likely that the substrate would stay wetter for a longer period after rain (depending on how quickly the perforated pipe at the bottom of the planter removed excess water) which could significantly alter the success rate of the trialled plants. It would, therefore, be of interest to re-run this trial using filtration planters to see if the same results in terms of plant success were achieved. Furthermore species that did not perform so well in this trial (for example the *Geranium* and *Inula*) could perform better in a filtration planter.

8.2 The substrates

In section 7.1 it was noted that the plants in the clay based substrate often looked greener than those in the St. Pölten substrate which looked more yellow. The plant growth graphs in section 7.2 also frequently revealed that the plants in the clay based substrate were able to establish themselves and start growing more quickly than in the St. Pölten substrate. It is likely that the improved clay based substrate offered more nutrients to the plants and that it was easier for the plant roots to access them than in the very stone based St. Pölten substrate. The extremely free draining nature of the St. Pölten substrate may also have contributed to these findings; in that more water was retained in the clay based substrate and was then available for the plants.

The very large and deep cracks seen in the clay based substrate (as mentioned in section 7.1) due to the prolonged dry spell are a direct result of the use of clay. Although cracks also appeared in the St. Pölten substrate these were much smaller. These cracks perhaps contributed to subsequent rain running down them and away from the plants more quickly, but otherwise did not seem to adversely affect the performance of the plants. The cracks did not look good and detracted from the aesthetics of the display at this time, although in future years due the complete ground cover achieved by the *Gypsophila repens* they would be far less noticeable. It can, therefore, be seen as an accepted consequence of using a clay based substrate but one that is not necessarily detrimental to the feasibility of such a scheme.

8.3 The plant species trialled

Alchemilla sericata 'Gold Strike' flowered well in the trial throughout June and the first half of July. Although not done in this trial it is possible to cut back *Alchemilla* after flowering, which often then produces a second flush of flowers later in the season. The growth of the plants (particularly in terms of spread) was also good in both substrates. Overall because of its' good flowering and growth this species was a success in both the clay based substrate and St. Pölten substrate and can be strongly recommended.

The *Aquilegia alpina* flowered well during the trial with their vivid blue flowers carried high upon long stalks which raised them up above the sides of the planters, making for attractive accents at the time. They initially grew much better in the clay based substrate than the St. Pölten substrate indicating that the plants can establish themselves much more easily in the clay based substrate. In the early part of the trial

they certainly struggled in the St. Pölten substrate with two plants dying and the rest looking in poor condition.
As the plants freely set seed they could well multiply over time and appear in other places in the planters or outside of them – particularly if seed was carried out through the overflow during a large stormwater event. This is an aspect that should be considered, as if it is not desired, time would need to be spent weeding out new seedlings in the planter, or an alternative species should be used.
Due to their good flowering and growth, this species was a success in the clay based substrate and can be recommended particularly for use in private gardens. In public areas the free seeding nature of the plants could be seen as problematic as the weeding out of seedlings would add cost for the council. This as well as their poorer performance in the St. Pölten substrate means they are not recommended for use in public areas.

Calamagrostis brachytrica were the largest plants in the trial and did add bulk to the display. However, none of the plants flowered in either substrate. If the trial was continued over a second year it would be interesting to see if they would flower then. An observation made during the trial was that by mid-October the plants were starting to go yellow, this followed a relatively dry period in the second half of September. This concurs with a result seen by YUAN & DUNNETT 2018 (as mentioned in chapter 5.1) where they found *Calamagrostis brachytrica* "[…] showed stress due to the shortages of soil moisture during the draining stages, and only recovered chlorophyll fluorescence in waterlogged or damp soils." (YUAN & DUNNETT, 2018).
Despite the negative aspects of yellowing leaves and a failure to flower, as the plants established quite quickly and grew quite well adding structure to the planting, and survived the trial, they can be recommended for use in the clay based substrate as well as in the St- Pölten substrate.

Geranium x cultorum 'Sabani Blue' failed to flower in either substrate. If the trial was continued for a longer period, it could be investigated if they would flower in the second year once the plants were more established. The initial growth appears faster in the clay based substrate indicating that the plants can establish themselves quicker in this substrate than in the St. Pölten substrate. The plants added structure to the planting and grew well, but as their main purpose was to flower in the early season they didn't perform as expected and can only be recommended for use in either substrate if they are found to reliably flower in future seasons.

Gypsophila repens began flowering much earlier in the clay based substrate following a trend of several of the plant species which seemed to establish themselves more quickly in the clay based substrate than in the St. Pölten substrate. The small white flowers added a pleasing contrast to the blue and yellow colour scheme and lightened up the ground in the planters amongst all of the other green foliage. The extensive ground coverage seen in both planters by the end of the trial should have a very positive effect on the amount of weeding that is required in future years. It should also help to reduce evaporation from the surface of the substrate. Due to its successful flowering and excellent ground covering growth *Gypsophila repens* can be highly recommended for use in both the clay based and St. Pölten substrate planters.

Hemerocallis x cultorum 'Stella d'Oro' flowered well with relatively large egg-yellow flowers held up on tall stalks which certainly shone out from the planters during this time. Generally only a few flowers per planter were to be seen at any one time, so it would be recommended to plant them together in larger groups to create more of an impact. Overall this species was a success in both substrates and can be strongly recommended.

Inula ensifolia started the trial well and was flowering in both planters in early July. However, a large difference between the two planters then emerged - in the clay based substrate the flowering continued until mid-August whereas in the St. Pölten substrate it continued until mid-October. The plants in the St. Pölten substrate also grew considerably more (nearly doubling their spread and nearly tripling their initial height) than in the clay based substrate. By the end of the trial the plants in the clay based substrate had largely all disappeared. Consequently this species cannot be recommended for use in a clay based substrate, but could be used in a stormwater planter containing the St. Pölten substrate.

Pennisetum alopecuroides 'Hameln' flowered with white fluffy seed heads which made for a dynamic display especially when moving in the breeze, and showed up well against the green foliage of the other plants. Although the growth rates were very similar across both planters, as noted with some other species the height of the plants in the clay based substrate began to increase sooner than it did with the plants in the St. Pölten substrate. This indicates that the plants establish themselves more quickly in the clay based substrate. As the plants all grew successfully, and flowered well for a long time this species can be strongly recommended for use in the clay based and St. Pölten substrate.

Veronica teucrium 'Knallblau' flowered for one month in the trial, but the plants at this time were still small and so the flowers did not show up as well as other species used in the trial. By the end of the trial the plants in the clay based substrate had reached their full height, as well as increasing their spread, so it is likely that the flowering display in future years would have more impact. The growth rates between the two planters was extremely similar but with the plants in the St. Pölten based substrate not quite reaching their full height by the end of the trial. As the plants grew well and are likely to offer a better flowering display in future years - particularly if planted together in groups to make more impact - they can be recommended for use in both planters.

Two of the plants trialled - the *Calamagrostis b*rachytricha and the *Geranium x cultorum* 'Sabani Blue' - grew well but failed to flower. Two possible explanations for this could be the dry conditions which were exacerbated by the very free-draining substrate which caused the plants not to flower; a second explanation could be that these plants concentrated their energy on growing and establishing themselves in the first year and would then flower in subsequent years. The first of these theories could be tested by re-running the trial using filtration planters as mentioned in section 8.1. The second by running the trial over a longer period of two to three years to see if flowering occurs after the first year.

8.4 Soil moisture tolerance

The soil moisture tolerance of the species trialled as detailed in section 6.3 seems to have had little conclusive influence on the results.

All of the plants trialled were suitable for Mesic (2) conditions.

The *Calamagrostis brachytrica*, *Geranium x cultorum* ‘Sabani Blue’, *Hemerocallis x cultorum* ‘Stella d’Oro’, and *Pennisetum alopecuroides* ‘Hameln’ are category 2 (Mesic) only. Amongst these the *Hemerocallis x cultorum* ‘Stella d’Oro’ and *Pennisetum alopecuroides* ‘Hameln’ performed very well and are highly recommended whereas the *Calamagrostis brachytrica* and *Geranium x cultorum* ‘Sabani Blue’ performed much less well in the trial.

Two of the species - *Alchemilla sericata* 'Gold Strike' and *Aquilegia alpina* - were also suitable for Damp/moist (3) conditions with the *Alchemilla sericata* 'Gold Strike' performing very well and being highly recommended for use, while the *Aquilegia alpina* performed well in the clay based substrate but less well in the St. Pölten substrate which is more free-draining and less moisture retentive, which could explain the reason for this.

The *Gypsophila repens*, *Inula ensifolia* and *Veronica teucrium* ‘Knallblau’ were all also suitable for Dry (1) conditions with the *Gypsophila repens* performing extremely well, the *Inula ensifolia* performing poorly in the clay based substrate and reasonably in the St. Pölten substrate, while lastly the *Veronica teucrium* ‘Knallblau’ performed well in both substrates.

With this mix of results it is, therefore, not possible to conclude that plants that were only suitable for category 2 (Mesic), or plants that were suitable for both Mesic (2) and Damp/moist (3) conditions, or plants suitable to Mesic (2) and Dry (1) conditions performed better or worse in the trial.

9. Conclusion

Which of the plants trialled can be recommend for use in a stormwater planter on the heavy clay soil in and around St. Pölten?

Alchemilla sericata 'Gold Strike', *Gypsophila repens, Hemerocallis x cultorum* 'Stella d'Oro' and *Pennisetum alopecuroides* 'Hameln' all performed very well in the trial and can be strongly recommended. *Aquilegia alpina* can also be recommended as long as its tendency to freely set seeds will not cause a problem either within the planter or the wider environment. Despite not flowering during the trial *Calamagrostis b*rachytricha and *Geranium x cultorum* 'Sabani Blue' can also be recommended for the structure they bring to the planting and the likely hood that they would flower in future years. Finally *Veronica teucrium* 'Knallblau' also grew well and is likely to make more of an impact in future years having reached its full size during the trial.

Which of the plants trialled are unsuitable for use on heavy clay soil in a stormwater planter?

Inula ensifolia despite flowering well in July and August did not perform well in the clay based substrate as most of the plants did not survive until the end of the trial. As the plants did survive and flowered for much longer in the St. Pölten substrate it shows they can be used in a rain garden but are unsuitable for use in heavy clay soil.

Does the planting combination used provide an attractive display over the growing season?

The early part of the season (May and June) saw the flowering of a few species but largely due to the small size of the new plants the display lacked impact. This is likely to be better in future years as the plants mature. Planting an alternative species to the *Geranium* which failed to flower would also add more colour at this time. The inclusion of spring flowering bulbs (not part of this trial) could also be used to enhance the aesthetics earlier in the year.

The peak of the display was in July and August. By this time the plants were starting to fill out and the display had more impact. The fact that the colour scheme had changed from blue in the early season to yellow was also pleasing and gave a new dynamic to the display. Alternatively as these two colours complement each other in planting schemes, further varieties and species could be trialled to enable both colours to be flowering in the display at the same time. The addition of white flowers (*Gypsophila*) blended well with the green foliage of other species and helped to lighten up the ground level inside the planters.

The end of the season (September and October) should have been dominated by the grasses. The failure of the *Calamagrostis* to flower, and the yellowing of its foliage did somewhat detract from the display, while the dynamic aesthetics of the successful *Pennisetum* demonstrated what should have been.

In all considering the display was in its first year it was good. The planting of more of the same species together in clumps (as opposed to individually spaced out for the purposes of the trial) would certainly make more impact. The replacement of the *Inula* for another species as well as possibly replacing the *Geranium* and the *Calamagrostis* if they continue to fail to flower would also further enhance the attractiveness of the display.

Does the stormwater planter require additional irrigation during long dry periods?

Due to the exceptionally low amount of rainfall in June and the fact that the plants were not yet fully established they did require additional irrigation once at this time. However, during the rest of the trial the planters did not receive any additional irrigation; this includes during a second dry period in August where only half the average monthly rainfall fell.

How much maintenance is required to keep the display looking good?

The planters were weeded three times during the trial taking no more than 10 minutes per planter on each occasion. As the ground covering plants had achieved virtually 100% ground cover by the end of the trial it is anticipated that fewer weeds would occur in future years. This could also be further improved by using a mulch on top of the substrate. At the end of the season most of the plants could be cut back to improve their appearance over the winter. Cutting back of the grasses should be left until the end of the winter as they still add structure and have a striking visual impact when frosted (see figure 52), they also provide useful cover for wildlife during the winter.

Summary

Overall the trial was a success with most of the species that were trialled growing and flowering well on the clay based soil. In particular *Alchemilla sericata* 'Gold Strike', *Gypsophila repens, Hemerocallis x cultorum* ‘Stella d’Oro’ and *Pennisetum alopecuroides* ‘Hameln’ all performed very well and can be strongly recommended for use in this way. Other trialled species such as the *Calamagrostis b*rachytricha and *Geranium x cultorum* ‘Sabani Blue’ showed some success but would benefit from a longer trial period, to fully test their suitability.

In a wider context rain gardens have many advantages over traditional (pipe based disposal) methods of dealing with rainwater particularly in urban areas. It is, therefore, unsurprising that they are being increasingly installed in many cities around the world. If their use can be encouraged in domestic gardens as well, the accumulative positive effects of all of these rain gardens would be enormous. In areas where the existing soil is deemed unsuitable for rain gardens (for example, heavy clay) then expensive soil replacement is often advocated. This trial has shown that soil replacement is not always necessary, and by improving the existing clay soil, and choosing the right species of perennials and grasses that it is possible to have an effective stormwater planter as part of a domestic (rain) garden.

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13. Index of Figures

14. Index of Tables